

SEPTEMBER 1954



VOL. 46 • NO. 9

Journal

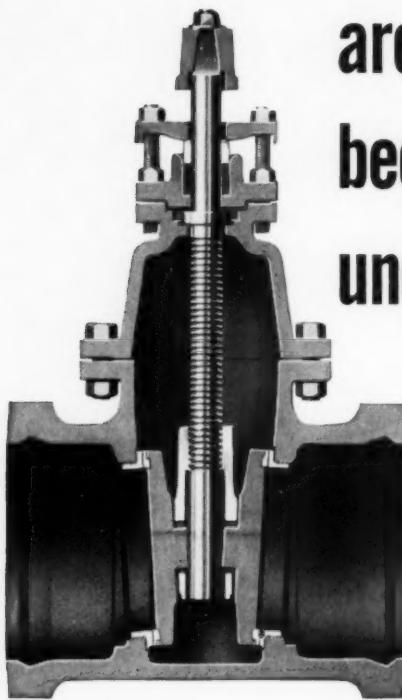
AMERICAN
WATER WORKS
ASSOCIATION

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are reliable
because they are
uncomplicated



Available with mechanical joint connections.

There's a sort of reverse English to designing R. D. Wood Gate Valves. The point is to make them as simple as possible, to eliminate all the ingeniously complicated parts that look good in the blueprint but cause operating failures deep down in the lines. You'll appreciate their rugged simplicity when you put them to the test. R. D. Wood Gate Valves are built to function for generations of trouble-free flow control.

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Journal

AMERICAN WATER WORKS ASSOCIATION
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September 1954
Vol. 46 • No. 9

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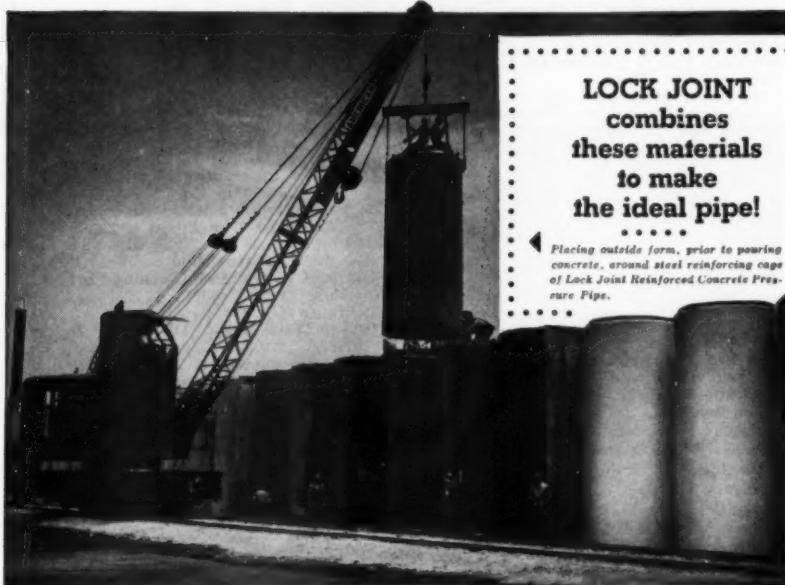
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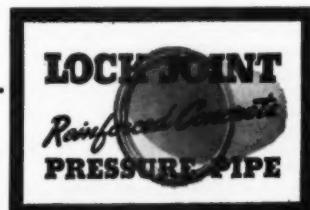
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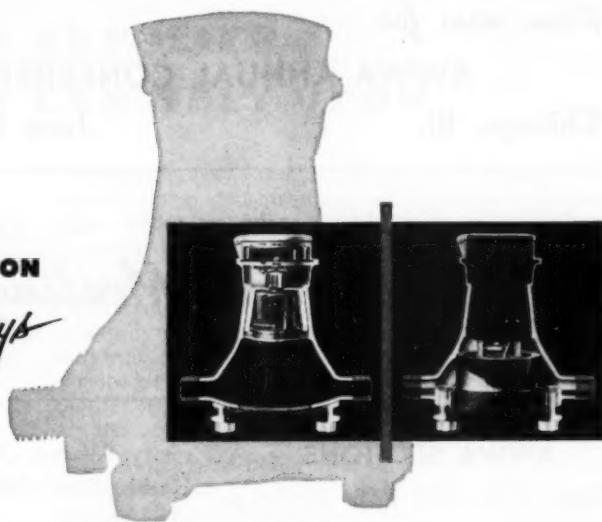
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Plan now for

AWWA ANNUAL CONFERENCE

Chicago, Ill.

June 12-17, 1955



Coming Meetings

AWWA SECTIONS

Sept. 9-10—New York Section at Montauk Manor, Montauk, L.I. Secretary, Kimball Blanchard, Rm. 1922, 50 W. 50th St., New York 20, N.Y.

Sept. 15-17—Michigan Section at Occidental Hotel, Muskegon. Secretary, T. L. Vander Velde, Chief, Secretary of Water Supply, State Dept. of Health, Lansing 4, Mich.

Sept. 20-22—Kentucky-Tennessee Section at Andrew Jackson Hotel, Nashville, Tenn. Secretary, J. Wiley Finney Jr., Asst. Director, Div. of San. Eng., State Dept. of Public Health, 420—6th Ave., N., Nashville 3, Tenn.

Sept. 22-24—Ohio Section at Biltmore Hotel, Dayton. Secretary, M. E. Druley, Manager, Dayton Power & Light Co., Wilmington, Ohio.

Sept. 26-28—Missouri Section at Hotel Governor, Jefferson City. Sec-

retary, Warren A. Kramer, Div. of Health, State Office Bldg., Jefferson City, Mo.

Sept. 28-30—Wisconsin Section at Hotel Northland, Green Bay. Secretary, Leon A. Smith, Supt. Water & Sewerage, City Hall, Madison 3, Wis.

October 4-5—Maritime Branch, Canadian Section at Hotel Brunswick, Moncton, New Brunswick. Secretary, J. D. Kline, P.O. Box 574, Halifax, N.S.

Oct. 6-8—Minnesota Section at Lowry Hotel, St. Paul. Secretary, Leonard N. Thompson, Gen. Mgr., Water Dept., St. Paul 2, Minn.

Oct. 13-15—Iowa Section at Hotel Roosevelt, Cedar Rapids. Secretary, H. V. Pedersen, Supt. of Water Works, Municipal Bldg., Marshalltown, Iowa.

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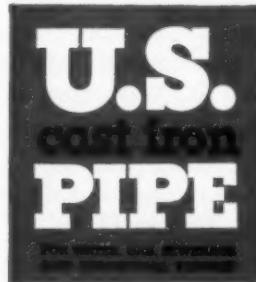
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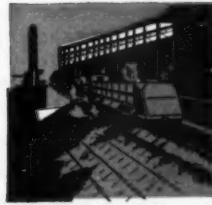


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A wholly integrated producer . . . from mines and blast furnaces to finished pipe.



Coke Ovens



Blast Furnaces



Pipe Plants

Coming Meetings

(Continued from page 6)

Oct. 17-20—Southwest Section at Cortez Hotel, El Paso, Tex. Secretary, Leslie A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 24-27—Alabama-Mississippi Section at Tutwiler Hotel, Birmingham, Ala. Secretary, Charles W. White, Asst. San. Engr., State Dept. of Public Health, 537 Dexter Ave., Montgomery 4, Ala.

Oct. 26-29—California Section at Wilton Hotel, Long Beach. Secretary, Henry Franklin Jerauld, Asst. Supt. of Constr. & Operation, Water Dept., 1040 Manzanita, Pasadena 3, Calif.

Oct. 27-29—Chesapeake Section at Belvedere Sheraton Hotel, Baltimore, Md. Secretary, Carl J. Lauter, 6955—33rd St., Washington 15, D.C.

Nov. 3-5—Virginia Section at Jefferson Hotel, Richmond. Secretary, J. P. Kavanagh, 213 Carlton Terrace Bldg., Roanoke 11, Va.

Nov. 4-6—New Jersey Section at Madison Hotel, Atlantic City. Secretary, C. B. Tygert, Wallace & Tiernan, Inc., Box 178, Newark 1, N.J.

Nov. 7-10—Florida Section at Soren Hotel, St. Petersburg. Secretary, Harvey T. Skaggs, Secy. & Gen. Mgr., Amica-Burnett Chemical Co., Box 2328, Jacksonville, Fla.

Nov. 8-9—West Virginia Section at Prichard Hotel, Huntington. Secretary, H. K. Gidley, Director, Div. of San. Eng., State Dept. of Health, Charleston 5, W.Va.

Nov. 8-10—North Carolina Section at George Vanderbilt Hotel, Asheville. Secretary, E. C. Hubbard, Exec. Secy., State Stream Sanitation Com., Box 2091, Raleigh, N.C.

Nov. 9-10—Rocky Mountain Section at Broadmoor Hotel, Colorado Springs, Colo. Secretary, George J. Turre, San. Engr., Board of Water Comrs., Box 600, Denver, Colo.

Dec. 2-4—Cuban Section at Sociedad Cubana de Ingenieros, Havana. Secretary, Laurence H. Daniel, Pres., Laurence H. Daniel, Inc., Baratillo 9, Havana, Cuba.

OTHER ORGANIZATIONS

Sep. 28-30—South Dakota Water & Sewage Works Conference, in Mitchell, S.D.

Oct. 3-6—New England Water Works Assn., Poland Springs, Me.

Oct. 11-14—Federation of Sewage & Industrial Wastes Assns., in Cincinnati.

Oct. 11-15—American Public Health Assn., in Buffalo

Oct. 17-20—American Society of Civil Engineers, in New York City

Oct. 19-21—Public Utilities Sessions, National Safety Congress, Chicago

Oct. 19-22—Pennsylvania Water Works Assn., in Atlantic City, N.J.

Nov. 17-19—Water Works Management Short Course, at Univ. of Illinois, Allerton Park, Ill.

Nov. 28-Dec. 3—American Society of Mechanical Engineers, in New York

Question:

**Can we get
installation savings
and performance too?**

Answer:

**Yes...with the new
Ring-Tite Coupling**



Speeds assembly of Transite Pressure Pipe

In state after state, contractors are learning that Transite® Pressure Pipe and the new Ring-Tite® Coupling provide fast, sure pipe line assembly with tight, dependable joints . . . strength to assure lasting trouble-free water mains through the years.

With Ring-Tite, installation costs less—assembly follows digger closely. Typical contractors' comments: "On entire job, trencher and backfiller seldom over 150 feet apart . . ." "Laid 6" Class 150 Ring-Tite at a rate of 5000 feet per 8 hours."

The design of the Ring-Tite Coupling permits quick, easy alignment. To assemble, rubber rings are simply popped into grooves. Then lubricated pipe ends slide in under rings smoothly, surely.

Pipe ends stop positively . . . with ends automatically separated within coupling. This separation gives the line flexibility to withstand shock and vibration, relieves line stresses, permits conformance to curves. Installations can be completed under adverse weather, temperature or terrain conditions. Moreover, there is no complicated equipment required.

Transite Pressure Pipe and the Ring-Tite Coupling are made of asbestos and cement. They are strong and durable. They cannot rust, and are highly resistant to corrosion. Tested to A.W.W.A. specifications.

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*Sure, that old pump still works,
but how much does it cost to keep?*



That rugged old pump of yours may not be the bargain that it seems. Let's do some arithmetic. If the efficiency of the old pump is 75% vs. the 85% efficiency of the new pump, you are paying more to keep it than you would to replace it. That's because a new unit of equivalent output uses less power. Thus it soon saves its own cost—then begins to pay dividends.

Let's take a specific example—a water works pump

Old pump efficiency 84% 625 BHP

New pump efficiency 89% 590 BHP

35 BHP Saving

On the basis of 1¢ per KWH, the 35 BHP saving for a 5000-hour year (approximately 14 hours per day) amounts to \$1300. This saving, capitalized in 15 years at 5%, adds up to \$28,000. Yet the price of the new pump that saves \$28,000 is only \$4054.

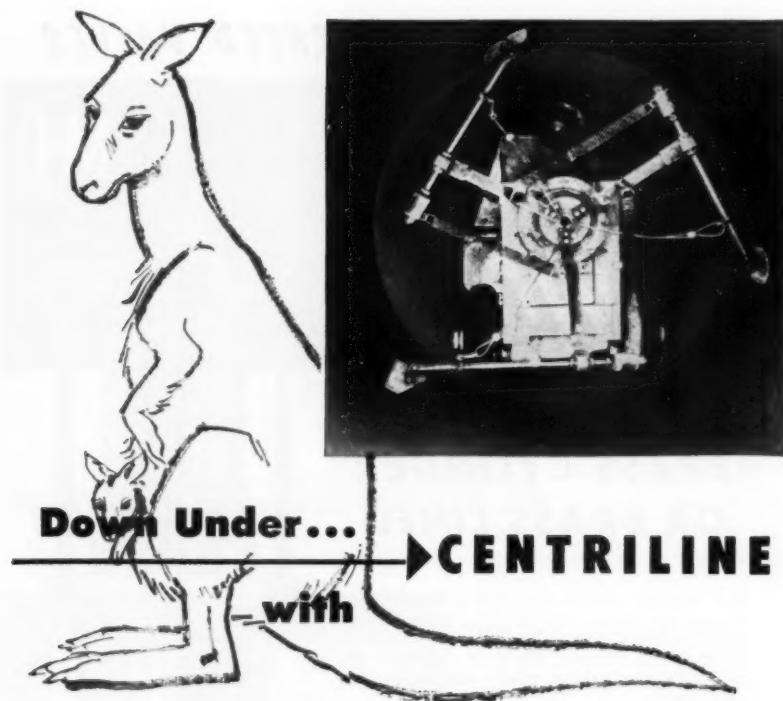
What would the pump replacement profit be in your particular case? Your De Laval representative can tell you exactly—in dollars and cents—as soon as he has the basic facts on your present installation. Call him in today or write to De Laval for Pump Fax Bulletin which includes a valuable "power-savings" chart.



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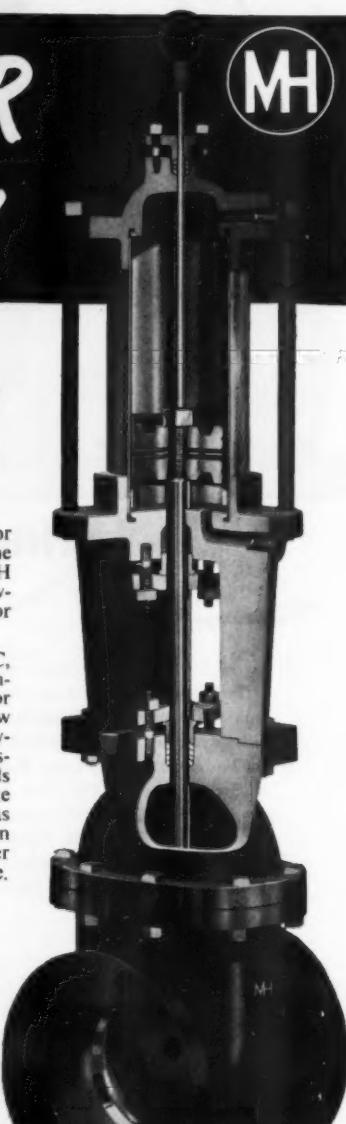
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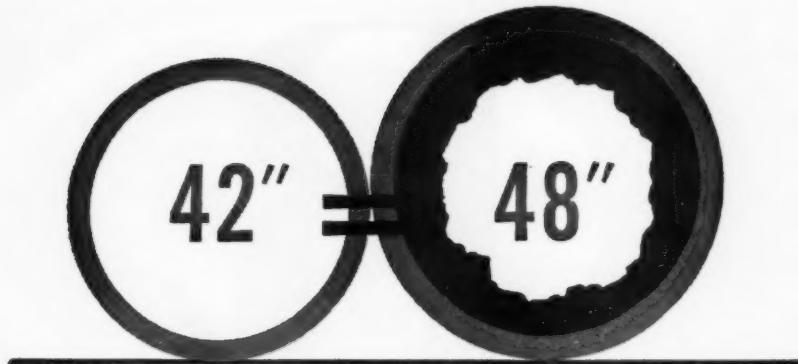
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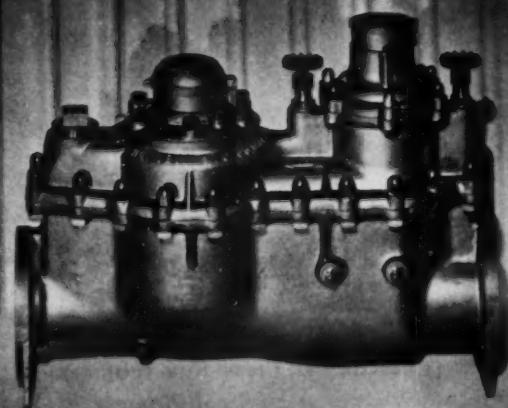
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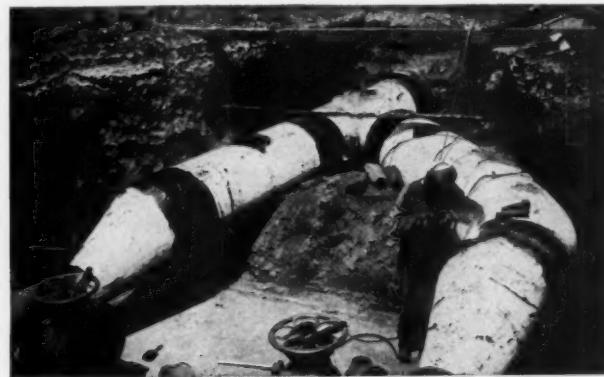
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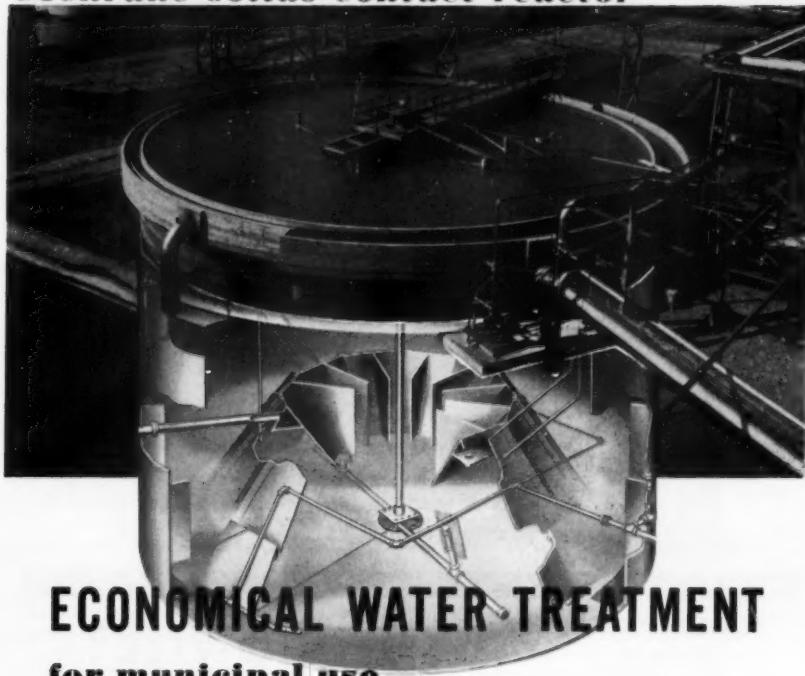
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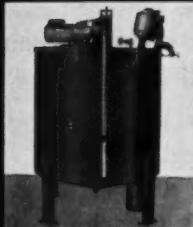
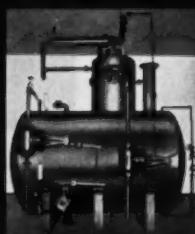
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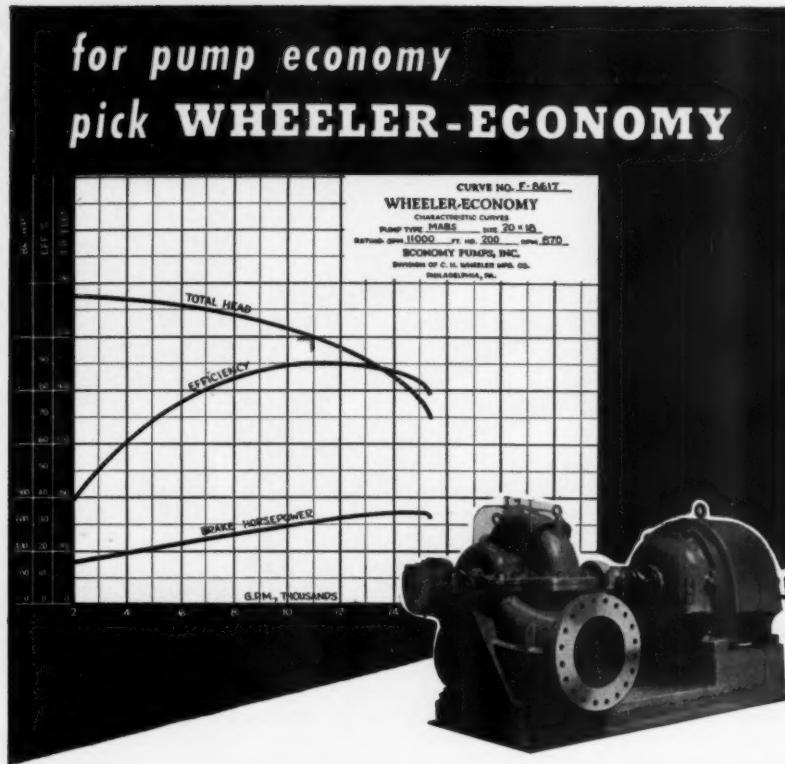
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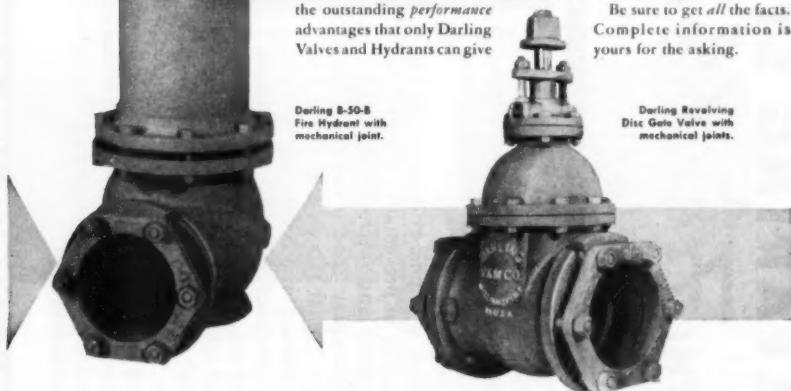
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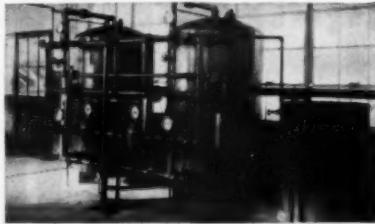
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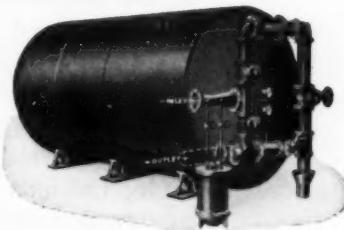
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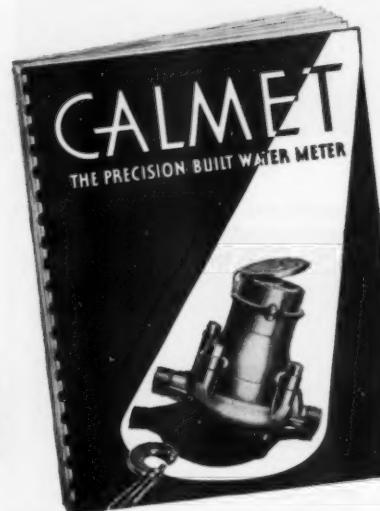
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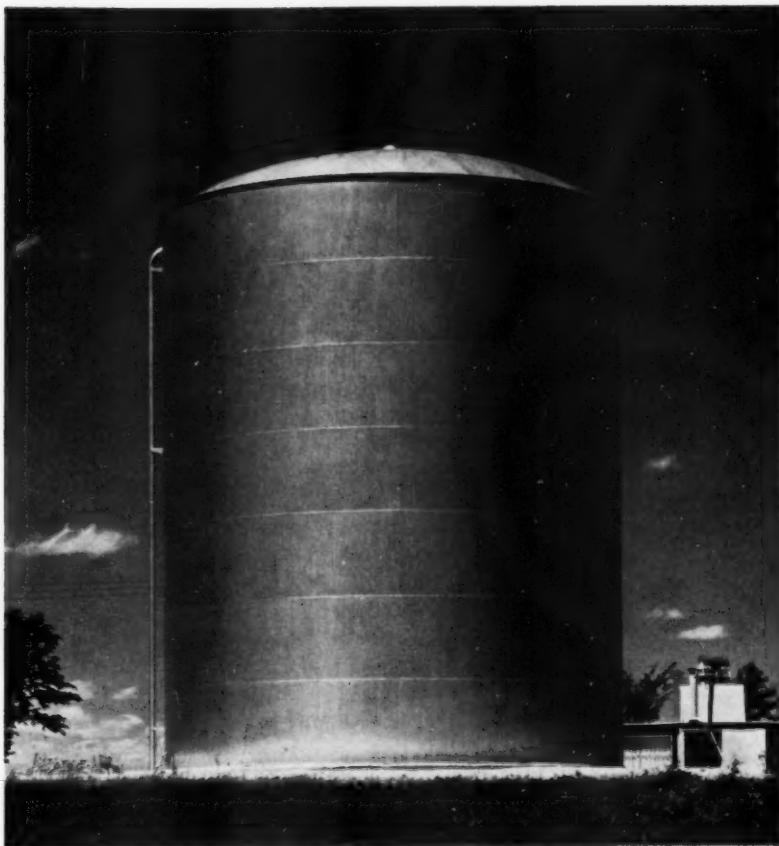
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Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 46 • SEPTEMBER 1954 • NO. 9

Quantitative Measurement of Rainfall by Radar

By **A. M. Buswell, G. E. Stout, and J. C. Neill**

A paper presented on May 25, 1954, at the Annual Conference, Seattle, Wash., by A. M. Buswell, Chief; G. E. Stout, Head, Meteorologic Subdiv.; and J. C. Neill, Meteorologist; all of State Water Survey, Urbana, Ill. (Investigation jointly sponsored by US Signal Corps Eng. Labs. and State Water Survey under Contract No. DA-36-039 SC 42446.)

THE standard rain gage does not give a good estimate of areal rainfall, but merely measures the rainfall in the immediate vicinity of the collector. During World War II it was observed by the military that certain radar frequencies were detectors of precipitation. At the close of the war preliminary work was done by the armed forces at the Massachusetts Institute of Technology on the detectability of meteorological parameters by radar. In 1948 the Illinois Water Survey became interested in the utility of radar for quantitative measurement of summertime precipitation in the state. Special networks of rain gages were established to define their accuracy at various gage densities and to check it against radar measurements of rainfall. This paper summarizes some of the results obtained from dense rain gage networks and from radar obser-

vation of rainstorms during the past 2 years.

Storm Rainfall Variability

Extreme variability of rainfall over small areas, 100 sq miles or less, has been recorded by gages spaced approximately 1½-2 miles apart (1). The variability of point storm rainfall amounts and the areal rainfall distribution patterns for several summer rainstorms are shown in Fig. 1-3. These isohyetal maps were prepared from 50 recording gages within a 96-sq mile area on the Goose Creek watershed. The network is centered approximately 20 miles west of Champaign-Urbana, Ill.

In Fig. 1, the rainfall patterns for Jul. 13 and 17, 1952, represent storms of short duration and very low average rainfall (less than 0.05 in.) over the network. The differences between in-

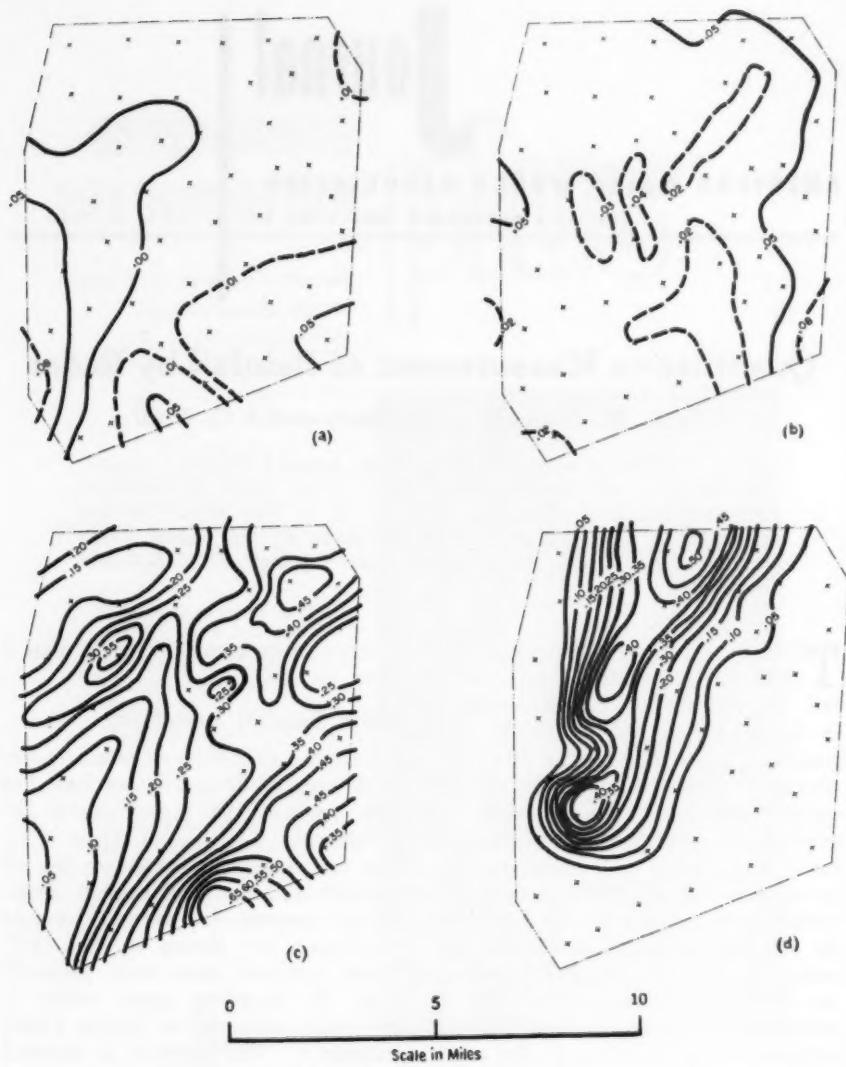


Fig. 1. Light-Rainfall Variability

The average amount and duration of rainfall on various dates (1952) were, respectively: (a) Jul. 13—0.03 in., 45 min; (b) Jul. 17—0.04 in., 20 min; (c) Jul. 16—0.26 in., 70 min; (d) Aug. 3—0.16 in., 10 min.

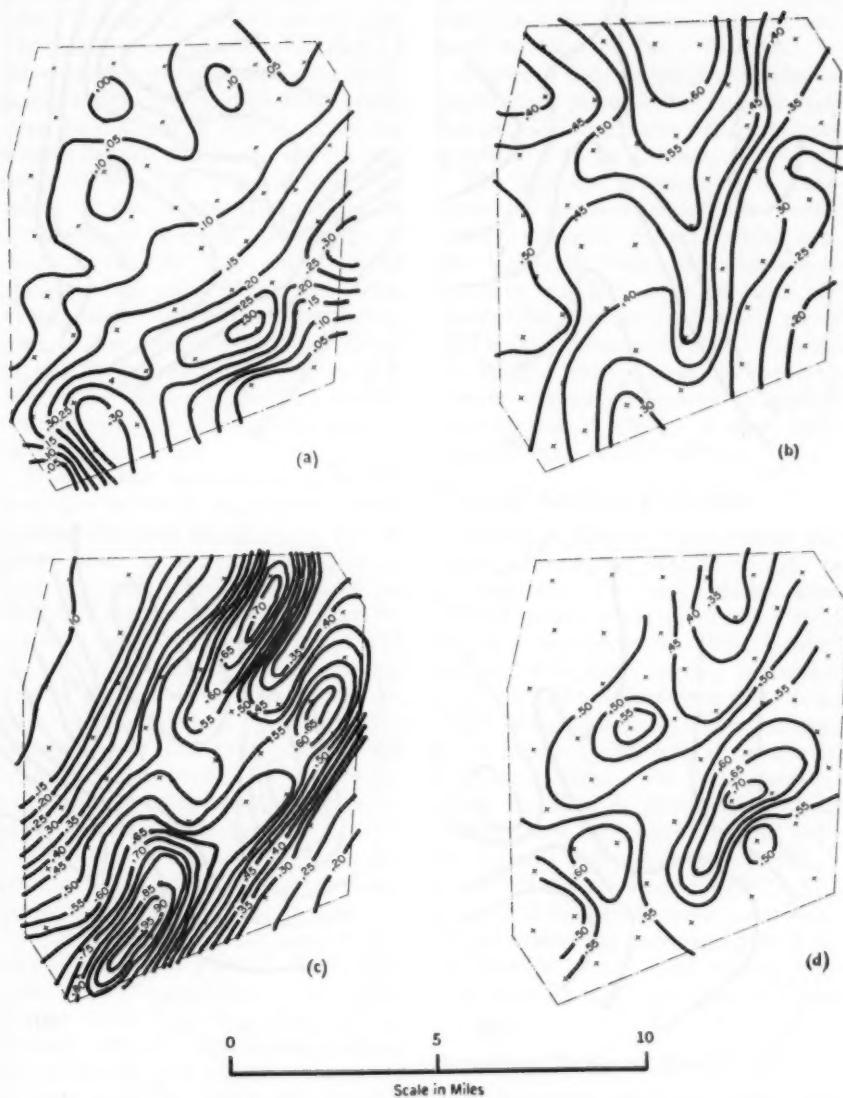


Fig. 2. Medium-Rainfall Variability

The average amount and duration of rainfall on various dates (1952) were, respectively: (a) Jul. 14—0.16 in., 10 min; (b) Jul. 7-8—0.40 in., 120 min; (c) Aug. 3—0.48 in., 105 min; (d) Jun. 20—0.52 in., 105 min.

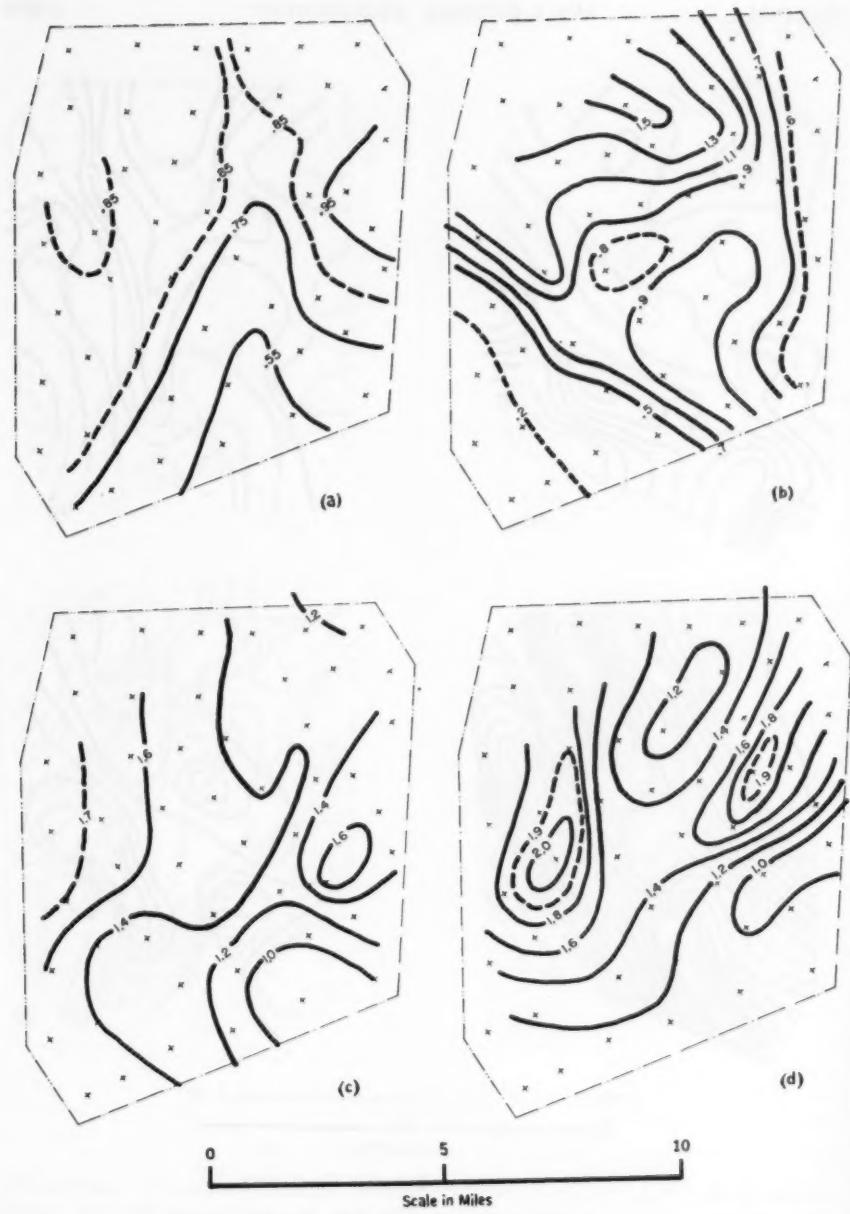


Fig. 3. Heavy-Rainfall Variability

The average amount and duration of rainfall on various dates (1952) were, respectively: (a) Jun. 21—0.79 in., 90 min; (b) Jul. 2—0.84 in., 180 min; (c) Jun. 13—1.41 in., 120 min; (d) Jun. 22-23—1.42 in., 180 min.

dividual gage readings likewise are small, amounting to 0.08 in. or less. The storms of Jul. 16 and Aug. 3 show rainfall patterns that are considerably more variable than those of the other two storms in Fig. 1. One has a mean rainfall of 0.16 in., and the second 0.26 in. The range of individual values on Jul. 16 was 0.05–0.65 in. in a distance of $3\frac{1}{2}$ miles. The storm of Aug. 3 exhibits very high rainfall gradients—up to 0.25 in. per mile. Precipitation was very intense over part of the network and diminished rapidly from the core to the outside edge of the rain area, leaving a considerable portion of the network without rainfall.

It is evident that several gages are necessary to obtain an accurate measurement of mean rainfall over the affected area for a storm like that of Aug. 3. One gage located near the center of the network would have recorded a rainfall amount of about 0.15 in., which, although a good representation of the network mean in this instance, tells little about the rainfall that occurred over the remainder of the network. Moreover, it is possible for rainstorms of this size to pass between gages spaced 8 miles apart.

The isohyetals shown in Fig. 2 represent rainfall of longer duration and greater average depth than that in Fig. 1. These four isohyetal maps represent a variety of rainfall distribution patterns and gradients. A second rainstorm on Aug. 3 produced three distinct cores of high rainfall within the 96-sq mile network, and there were several zones in which the rainfall gradient was of the order of 0.35 in. per mile. The range in point rainfall measurements was 0.10–0.95 in., a considerable variation for an area of this size. The rainfall cores and gradients in the other three diagrams in Fig. 2

are much less intense. No distinct rainfall centers were found in the network area for the Jul. 7–8 storm.

Figure 3 shows typical examples of distribution patterns for a mean rainfall of 0.75 in. or more occurring over a period of $1\frac{1}{2}$ hr or longer.

The isohyetal patterns have illustrated the fact that rainfall often varies widely. Several distinct rainfall centers for single storms are common in an area of 100 sq miles, and the amount of rainfall frequently varies 0.25 in. in a distance of 1 mile. Storms of long duration tend to produce greater relative uniformity in rainfall patterns than do storms of short duration and high rainfall rate.

Seasonal Rainfall Variability

During a thunderstorm season numerous rainstorms deposit rainfall on a watershed. The accumulation from several storms tends to produce areal rainfall distributions with smaller relative differences among individual point rainfall amounts than those from single thunderstorms. The variance in seasonal point rainfall amounts, however, is large. The three isohyetal maps in Fig. 4 illustrate seasonal thunderstorm rainfall variability over the Goose Creek network from Jun. 1 to Oct. 31 for the years 1951–53. The greatest difference between point rainfall amounts was approximately 2 in. in $1\frac{1}{2}$ miles for the 1951 season, 2 in. in 2 miles for 1952, and 2 in. in 1 mile for 1953.

Sampling Variance Study

A sampling variance study was made on point rainfall values for the purpose of obtaining an estimate of the standard error to be expected in calculating areal mean storm rainfall from various gage densities (2). In this study, the different sample sizes or

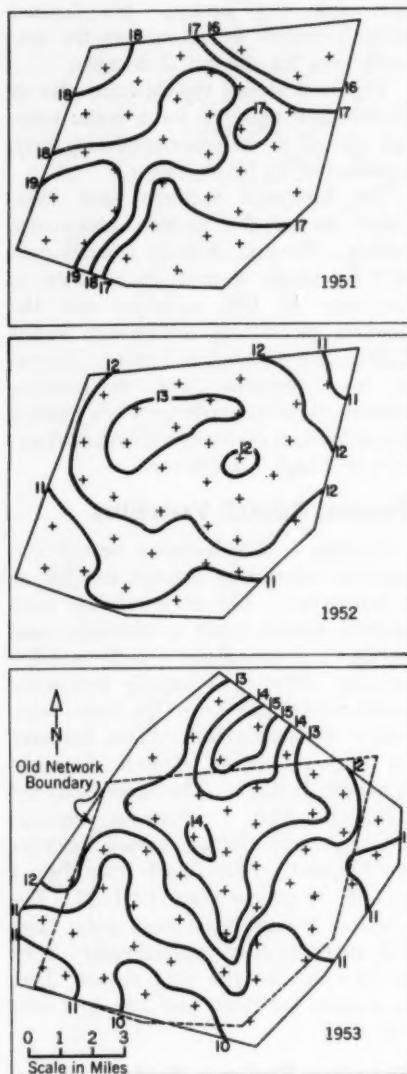


Fig. 4. Cumulative Rainfall

The average rainfall (in inches) for the period Jun. 1-Oct. 31 in the years 1951, 1952, and 1953 was, respectively: 17.32, 12.12, and 12.07.

gage densities were obtained by dividing the network area into sections and selecting gages located near the center of the sections. Figure 5 shows the relation of the sampling standard error to the storm size (as indicated by the gage network mean rainfall) and to the sample size (the number of gage observations included). It is evident from the graph that the expected sampling standard error increases as the storm size increases and as the number of gages in the sample decreases. For example, the error to be expected in the measurement of a $\frac{1}{2}$ -in. network mean rainfall with eight gages is 0.030 in., while, for a 1-in. mean rainfall, the error is 0.045 in. The errors to be expected for the same storm sizes when one gage is used are 0.102 in. and 0.151 in., respectively.

The sampling standard errors shown in Fig. 5 are essentially average errors in the measurement of areal mean rainfall for different storm sizes when various rain gage densities are used. It is important to note that average values always cover up the extremes. The diagram in Fig. 6 shows 95 per cent confidence bands for mean rainfall based on estimated mean rainfall samples from different gage densities. These bands include approximately 95 per cent of the individual deviations of sample means from the 50-gage network mean. Although the average expected errors shown in Fig. 5 may lead one to feel that the sampling errors are not very serious, Fig. 6 shows that a band of considerable width is necessary to encompass the greater part of the individual errors averaged in the expected standard error. For example, when a 1-in. mean rainfall is obtained with a density of one gage per 96 sq miles, the true network mean rain-

fall may be between 0.70 in. and 1.30 in. This is an error range of 0.60 in. or ± 30 per cent. As the number of gages used in obtaining an estimate of the mean rainfall is increased from one to 24, the 95 per cent confidence region narrows to 0.10 in. for a 1-in. mean rainfall.

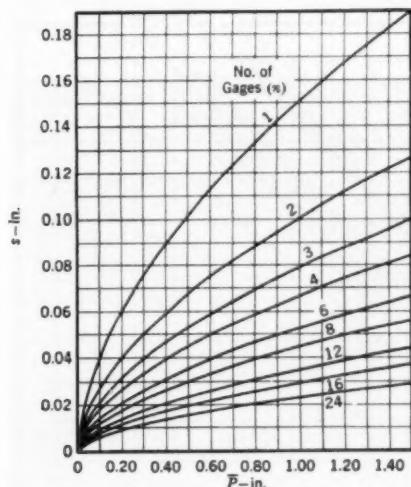


Fig. 5. Sampling Standard Error

Key: s, standard error of estimates for samples of size n (number of gages); \bar{P} , population mean rainfall based on 50 gages. Data for 45 storms occurring over Goose Creek network in 1952 and 1953.

Radar Measurement Program

Evidence has been presented that rainfall is variable and that a large number of gages are needed to obtain a good estimate of areal mean rainfall, especially when shower type precipitation is involved. This type produces most of the annual rainfall in Illinois.

The present network density in Illinois is approximately one gage per

225 sq miles, which does not provide the accuracy desired by engineers and hydrologists. The expense of increasing the density to that needed and of collecting and compiling the hydrological data would be prohibitive. Accordingly, the State Water Survey initiated an investigation in 1948 to determine the ability of radar to provide quantitative rainfall measurements. The Pfister Hybrid Corn Co., El Paso, Ill., cooperated in the first study to detect, track, and measure the areal extent of shower type rainfall. A war surplus 3-cm radar set was installed. A network of 35 stick and twelve recording rain gages was installed over an area of approximately 280 sq miles in the vicinity of El Paso, in order to obtain simultaneous surface rainfall measurements for correlation with the radar observations and for investigating thunderstorm rainfall variability (3).

Operations during the thunderstorm seasons of 1948-49 proved that radar could successfully detect, track, and indicate the areal extent of precipitation in showers and thunderstorms. An evaluation of the quantitative aspect of rainfall measurement with radar was begun in 1950. Concurrently with the State Water Survey's work, the University of Florida published the results of some analyses of radar rainfall data previously collected (4). Operations during the summer of 1950 were encouraging (5), although limited by the modification of the radar equipment for quantitative observations.

Early in 1951 the radar equipment was moved to the University of Illinois airport, near Champaign-Urbana, to facilitate operations. A concentrated network of 34 recording gages, with

12.648-in. diameter collectors and 6-hr charts, was installed over an area of 50 square miles on the Goose Creek watershed. During the 1952 thunderstorm season the program for quantitative measurement of rainfall with radar equipment was expanded con-

center rack consists of a receiver-indicator, a camera on a remote scope, a plotting board, and various controls. The unit on the right, known as an area integrator, will be discussed briefly later. The radar antenna is located on a 47-ft tower to obtain an

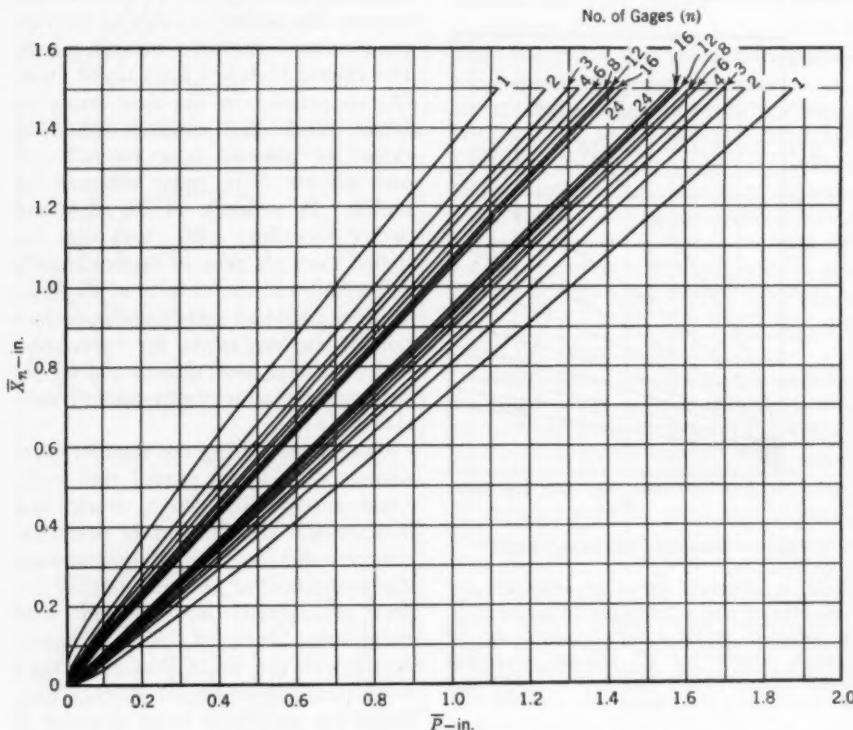


Fig. 6. Ninety-five Per Cent Confidence Limits

Key: \bar{X}_n , estimated mean rainfall for samples of size n (number of gages); \bar{P} , population mean rainfall based on 50 gages. Goose Creek data, 1952-53.

siderably with support from the US Army Signal Corps (6). The number of gages on the Goose Creek watershed was increased to 50 in 96 sq miles.

Figure 7 shows the main components of the APS-15, 3-cm wavelength radar set used in the program. The

unobstructed scanning view in the direction of the Goose Creek rain gage network.

Principle of Radar

Radar is a high-frequency radio device emitting a short, intense pulse of

energy that is focused into a narrow beam of invisible energy by a rotating antenna, much like a searchlight. This pulse of energy travels at the speed of light. If the beam strikes an object, such as an airplane or a group of raindrops in a cloud, a small portion of the energy is reflected back as an "echo" to the point of transmission. The return signal is amplified and pre-

theory that the energy (or power) received from raindrops may be expressed by the equation:

$$\frac{P_r R^2}{P_t} = K N d^6 \dots \dots \dots (1)$$

in which P_r is the power received, P_t is the power transmitted, R is the distance from the radar set to the re-

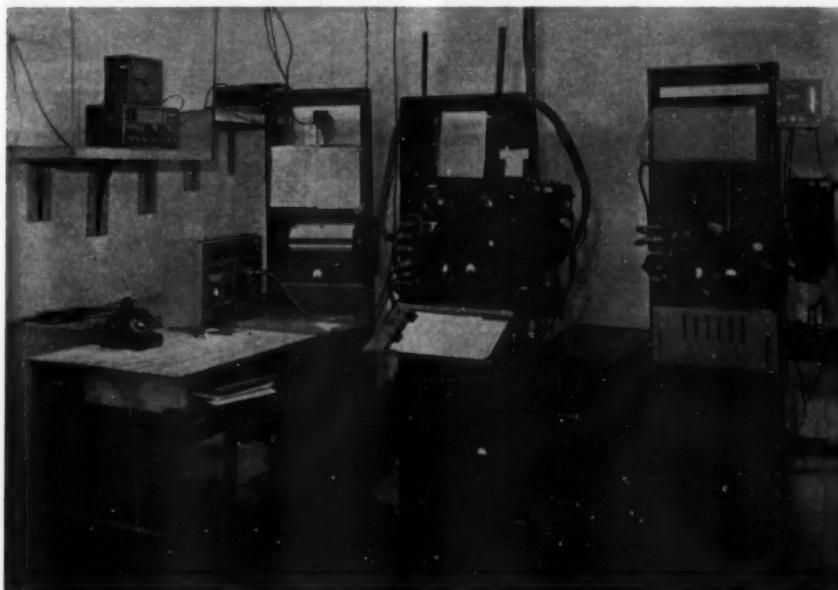


Fig. 7. Radar Room

The center rack consists of a receiver-indicator, a camera, a plotting board, and various controls. At right is an "area integrator."

sented on a cathode ray tube. The range and bearing of the object are readily determined.

Research in this field by previous investigators (7, 8) indicated that radar echoes from rain clouds are the result of the back-scattering of radio energy by raindrops falling through the atmosphere. It appears from the

flecting raindrops, N is the number of raindrops per unit volume, d is the diameter of the raindrops, and K includes a constant for the refractive index of water and a number of constants that are parameters of the radar set.

Radar does not measure rainfall intensity directly, but measures the re-

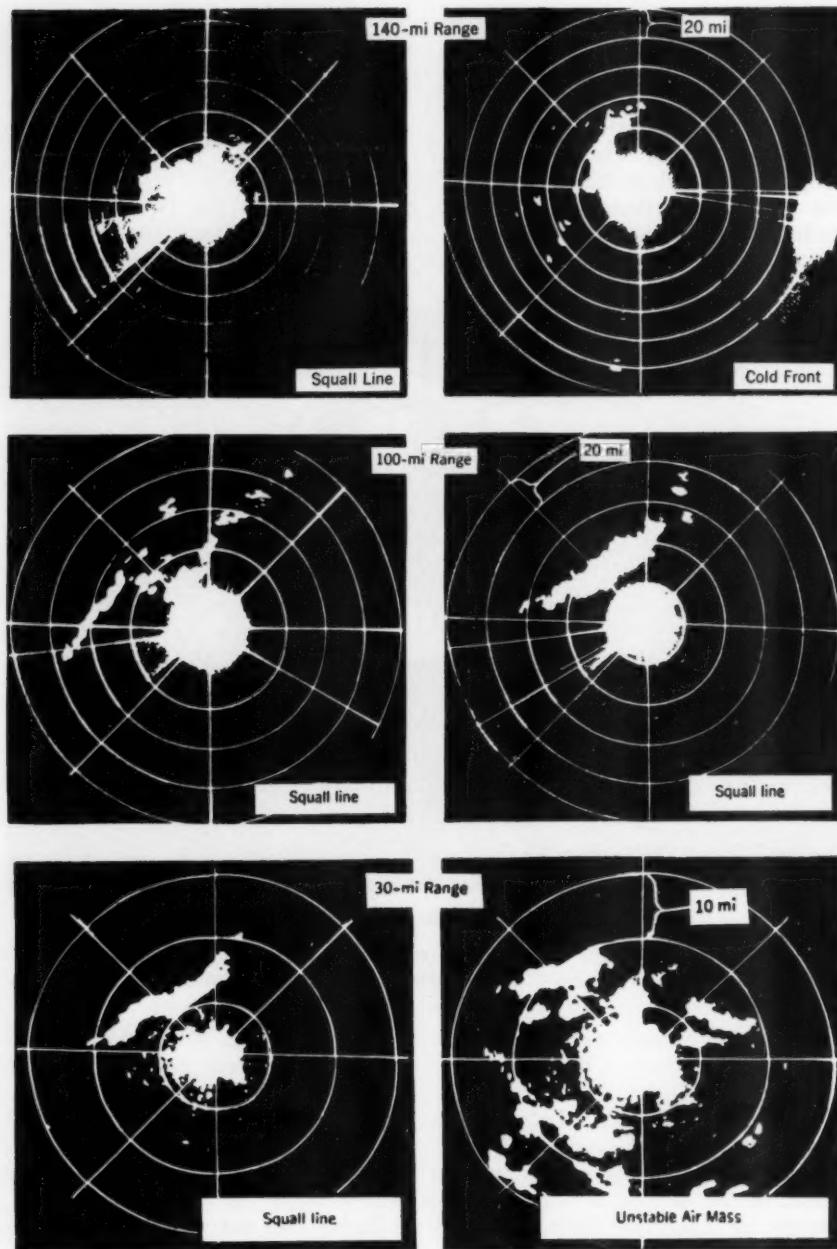


Fig. 8. Rain Echo Patterns

flectivity from Nd^6 . Several expressions for the rainfall rate in terms of Nd^6 have been obtained from raindrop size data. One of these expressions is:

$$Nd^6 = K_2 I^{1.53} \dots \dots \dots (2)$$

in which I is the rainfall intensity and K_2 is a constant of proportionality. When Eq 2 is combined with Eq 1, the resulting equation, written in logarithmic form, for the APS-15 model, is:

$$\log \frac{P_t R^2}{P_i} = 1.53 \log I - 10.932 \dots \dots \dots (3)$$

in which I is the rainfall rate in inches per hour.

Radar Patterns

The low-powered APS-15 radar set generally detects precipitation up to 140 miles. Numerous types of rainfall patterns are observed. Figure 8 gives some examples of the appearance of the plan position indicator (or face of the cathode ray tube) in different weather situations—cold front, squall line, and unstable air mass. Rainfall occurring in unstable air mass situations usually shows scattered echoes about the radar station, while a line of echoes is generally characteristic of cold-front and squall line rainfall. Shorter range settings (Fig. 8, bottom) provide an enlarged and more detailed record of a smaller precipitation area than longer ones and facilitate the analysis of data over the Goose Creek area.

Radar Rainfall Intensity Technique

Rainfall intensity data can be obtained from the radar echo pictures. A receiver sensitivity control system developed for use on the State Water Survey radar set automatically changes the radar receiver sensitivity in a step-

wise fashion, using fixed settings. Each time the receiver sensitivity is reduced, a greater rainfall intensity is required before an echo will appear on the plan position indicator. Thus, the system indicates areas of different rainfall intensities. An automatic film recording system was synchronized with the receiver sensitivity control so that photographs of rain echo areas could be taken.*

The results obtained by using the automatic sensitivity control and 35-mm film recording technique are illustrated in Fig. 9. Figure 9a shows the entire rain echo obtained with maximum receiver sensitivity during one 360-deg rotation of the radar antenna. As the next rotation began, the receiver sensitivity was reduced to the second highest fixed setting, causing the areas of lightest rainfall to be eliminated (Fig. 9b). This process was repeated through a series of six steps, with the photographs showing smaller and smaller rainfall areas. The film record consists of repeated series of pictures taken at 1-min intervals during a storm.

As the radar tracks the path of a storm, a detailed record of movement and rainfall intensity is compiled. The date and time of each rainfall intensity area sample is also recorded on film. The photographs in Fig. 9 were taken with the range set at 30 miles.

Radar and Gage Comparison

The next question of interest is how well the low-power 3-cm radar record compares with the rain gage record on the ground. Superimposing the images of a series of photographs like those in Fig. 9 on a single base map

* The illustrations in Fig. 8 and 9 are photographs that have been reproduced here by a linecut (rather than the more usual halftone) process for improved clarity.

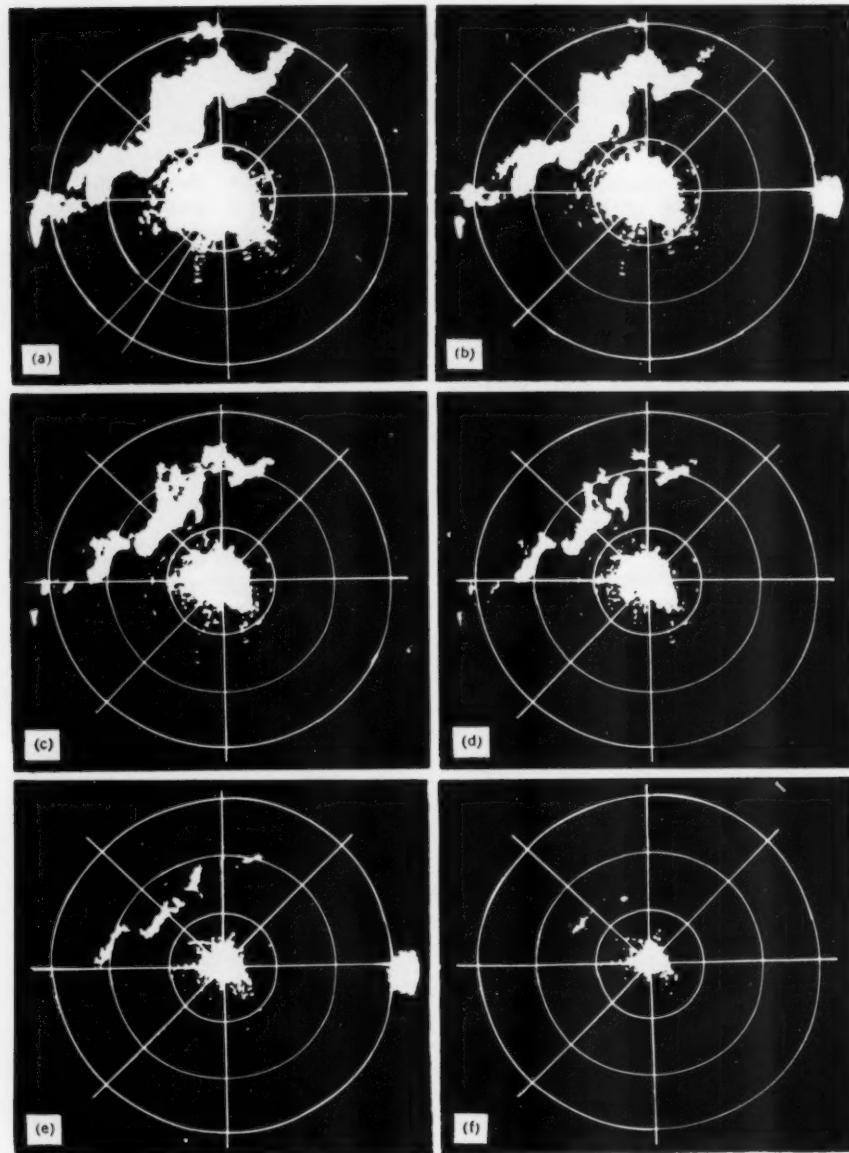


Fig. 9. Effect of Sensitivity Control

Photographs (a) through (f) show the results of progressively decreasing receiver sensitivity. The photographs were taken at 1-min intervals during a storm on Jun. 5, 1953.

permits the preparation of a radar rain intensity contour map for the Goose Creek area. Such maps can then be compared, as in Fig. 10, with others obtained from the network of recording gages. Each pair of patterns in Fig. 10 represents a time period of approximately 1 min.

There is considerable similarity between the two rainfall patterns and between their paths of movement across the area of the rain gage network. Variations between two in a pair may be partially attributed to the fact that radar "views" precipitation particles at an altitude above the ground. As the rain falls earthward, it drifts with the air currents and, consequently, does not strike the ground immediately below the point where it was recorded by the radar. In addition, the rainfall pattern from the gage network has to be prepared from point rainfall measurements that are 1-2 miles apart, whereas the radar observes precipitation over an entire area. Attenuation (loss of signal strength from scattering and absorption by intervening raindrops) often causes a loss of radar-indicated contour areas, especially on the far side of a storm (9).

In the Illinois Water Survey research program on the utility of radar in measuring rainfall, it was desired to determine the accumulation of rainfall as well as its distribution pattern. The rainfall intensity indicated for each echo contour shown in Fig. 10 can be computed from an expression like Eq 3 (page 847). The amount of rainfall represented by each isoecho contour map can be obtained by multiplying the area between contours by the proper rainfall rate and summing these products. By repeating this process for all minutes during the storm, the total rainfall volume can

be obtained. Dividing the latter figure by the network area gives the network mean depth.

Empirical Equation

The Illinois radar data indicated that previously published theoretical radar rainfall equations like Eq 3 gave rainfall intensities that were extremely small in comparison with those obtained from the rain gage network. Accordingly, it was decided to develop an empirical radar rainfall equation from radar and gage data collected during the thunderstorm season of 1953. The resulting equation was:

$$\log \frac{P_r R^2}{P_t} = 2.00 \log I - 11.641 \dots (4)$$

in which P_r is the power received (w), P_t is the power transmitted (w), R is the range (nautical miles) from the radar set to the reflecting raindrops, and I is the rainfall intensity (iph).

Areal mean rainfall depths for thirteen storm periods in 1953 were computed with both Eq 3 and Eq 4 (Table 1). Rain gage data indicated that the Goose Creek watershed accumulated an average depth of 3.96 in. during the thirteen storms. An estimate of 2.34 in. was obtained when the empirical equation (Eq 4) was used, while the theoretical equation (Eq 3) gave an estimate of 0.80 in. for the same storm periods. Table 1 shows that, in general, the empirical equation gave much larger and more accurate rainfall depths than Eq 3.

The preceding analytic process is very laborious and time consuming. In order to obtain a prompt estimate of areal mean rainfall, an area-rainfall integrator has been designed and built by State Water Survey electronic engineers. This device (shown at right in Fig. 7) electronically integrates the power returned from reflecting rain-

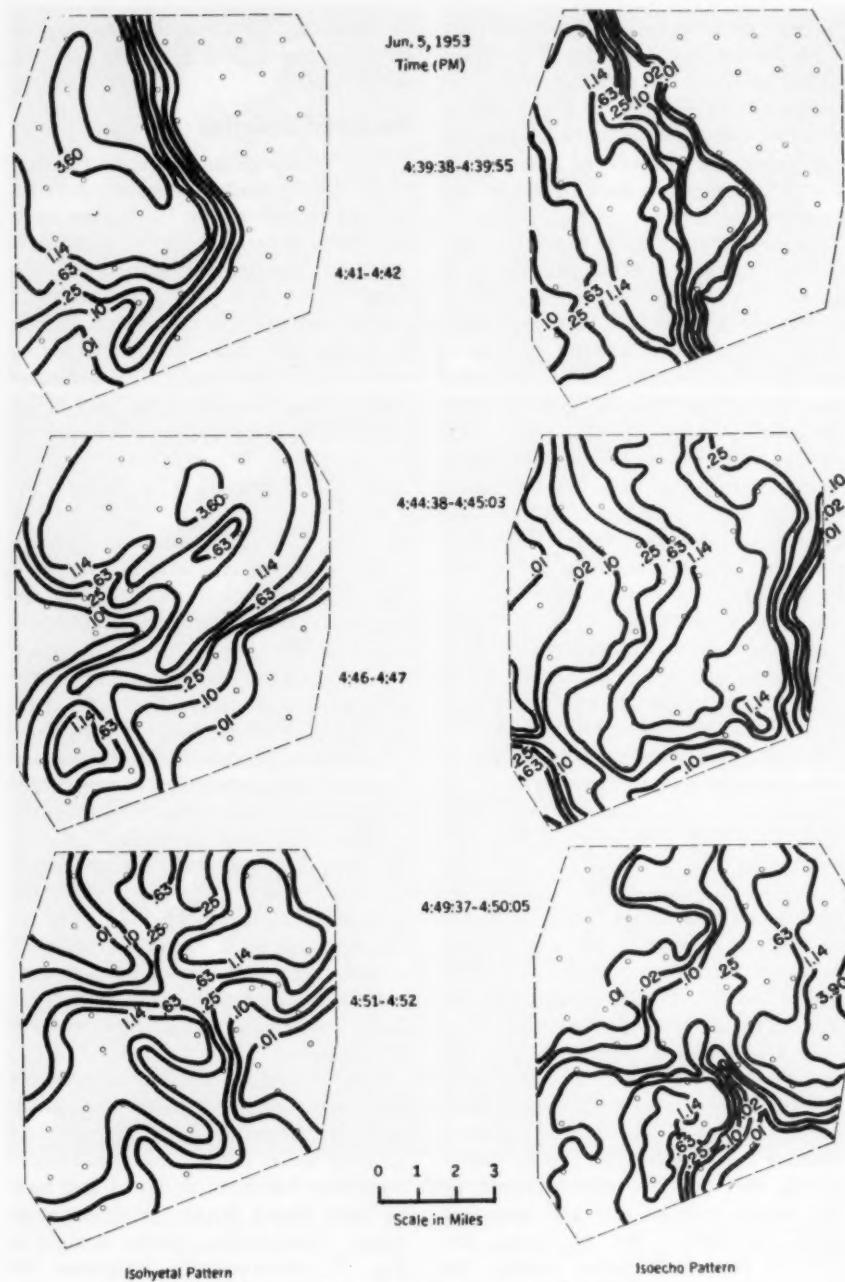


Fig. 10. Gage and Radar Maps of Rainfall (iph)

drops as the storm moves over an area. A cumulative record of the areal mean rainfall is automatically printed on a tape at 1-min intervals during a storm. At the end of the storm, an estimate of the accumulated areal mean rainfall is available as promptly as the point rainfall amount from a recording rain gage. The integrator is presently undergoing testing and minor modifications.

error (Fig. 5) for various gage densities. The results of this comparison are shown in the last column of Table 1. It was found that, in five storms, the deviation between the radar and the rain gage mean depth was considerably larger than the sampling error expected with one gage per 96 sq miles; in two storms, the deviation was slightly larger than that expected with one gage; in four storms, the deviation

TABLE 1
Radar and Rain Gage Mean Rainfall Comparisons

| Date (1953) | Gage Depth— <i>in.</i> | | | Radar Avg Depth— <i>in.</i> | | Radar Minus Gage Value† | Radar Accuracy Equivalent Gages‡ |
|----------------|------------------------|------|------|-----------------------------|------|----------------------------|---|
| | Min. | Avg | Max. | Eq 4 | Eq 3 | | |
| 4/9 | 0.00 | 0.05 | 0.23 | 0.18 | 0.06 | +0.13 | <1 |
| 4/24 | 0.09 | 0.12 | 0.48 | 0.25 | 0.06 | +0.13 | <1 |
| 5/16 | 0.03 | 0.21 | 0.48 | 0.26 | 0.06 | +0.05 | 1 |
| 6/5* | 0.13 | 0.35 | 0.55 | 0.32 | 0.12 | -0.03 | 5-6 |
| 6/8* | 0.31 | 0.60 | 0.94 | 0.48 | 0.22 | -0.12 | «1 |
| 6/25* | 0.01 | 0.71 | 1.25 | 0.25 | 0.10 | -0.46 | «1 |
| 7/2 | 0.03 | 0.44 | 1.64 | 0.06 | 0.01 | -0.38 | «1 |
| 7/5 | 0.64 | 0.82 | 1.03 | 0.13 | 0.04 | -0.69 | «1 |
| 7/17* | 0.01 | 0.15 | 0.37 | 0.15 | 0.05 | 0.00 | 50 |
| 8/3* | 0.00 | 0.03 | 0.23 | 0.03 | 0.01 | 0.00 | 50 |
| 8/7 | 0.21 | 0.37 | 1.55 | 0.15 | 0.05 | -0.22 | «1 |
| 8/8* | 0.00 | 0.09 | 0.59 | 0.05 | 0.01 | -0.04 | 1 |
| 9/18 | 0.00 | 0.02 | 0.07 | 0.03 | 0.01 | +0.01 | 1-2 |
| <i>Total</i> | | 3.96 | | 2.34 | 0.80 | | |

* Storms from which Eq 4 was obtained.

† Difference between radar depth computed from Eq 4 and average gage depth.

‡ Number of gages per 96 sq miles which would be expected to give a result as accurate as that obtained with radar using Eq 4.

Radar Accuracy

In experimental estimation of rainfall over a 96-sq mile watershed with radar instrumentation, it is necessary to adopt some standard as a basis for judging the reliability of the method. The rainfall sampling variance study, described previously, can be used for this purpose. The deviation (shown in the next-to-last column of Table 1) of the radar rainfall depth from the average on the Goose Creek gage network was compared with the sampling

compared favorably with the error expected with one or two gages; and in two storms, there was no deviation from the 50-gage network mean.

The very low radar estimates on Jul. 2 and 5 can be at least partially attributed to attenuation of the transmitted and received signals by the rainfall between the network area and the radar. With 3-cm radar, attenuation occurs during heavy rainfall, although, if longer wavelengths are used, the rainfall does not seriously weaken

the signal. On Jul. 5 there was rain at the radar station itself during the period of data collection. Except for that instance, all radar rainfall depths in Table 1 were between the lowest and highest gage readings on the network. When the proper radar wavelength for quantitative precipitation measurements is employed, the attenuation factor may be negligible.

Conclusion

With present accuracy, radar rainfall measurements can supplement thunderstorm rainfall sampling by the existing Illinois climatological rain gage network of approximately one gage for every 225 sq miles. The average area of a thunderstorm is approximately 8 sq miles, which corresponds to a diameter of about 3 miles for a circular cell. Therefore, it is possible for thunderstorms of this size to pass between gages of the Illinois network. Radar scans an entire area and is not subject to such measurement errors. Radar both locates and measures rainfall, whereas a rain gage cannot sample rainfall unless the rainstorm passes over it.

The results of the Illinois Water Survey 3-cm radar study are encouraging enough to indicate that further research on the quantitative measurement of rainfall with radar instrumentation should be carried out with up-to-date radar equipment using longer wavelengths, which are theoretically not as subject to raindrop attenuation.

Acknowledgment

The valuable assistance of M. Spock and L. Bivans, who were associated with the radar study project as meteorologists, is gratefully acknowl-

edged. R. Cipelle performed many of the computations. Credit is due various other staff members who either operated and calibrated the radar equipment or collected the rain gage data.

Quantitative measurement of rainfall by means of radar was first suggested by Byers (10) in 1948.

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Forecasting Water Supply Through Snow Surveys

By Fred A. Strauss

A paper presented on May 25, 1954, at the Annual Conference, Seattle, Wash., by Fred A. Strauss, Sr. Hydraulic Engr., Div. of Water Resources, State Dept. of Public Works, Sacramento, Calif.

CALIFORNIA, where snowmelt is the major source of water supply for the great Central Valley, maintains a cooperative snow survey program that makes possible the accurate forecasting of snowmelt runoff. As in other semiarid states of the West, practically no rain occurs in California from the beginning of June until the end of September. All water used during the summer must be supplied from the precipitation of the preceding winter, held over by natural agencies or artificial control.

For this purpose, nothing could be more suited than the topography and location of the Sierra Nevada, where there are vast watersheds upon which much of the winter's precipitation falls in the form of snow. The low temperatures at these high elevations prevent any appreciable amount of the snowpack from melting until summer comes to the valleys below, and even then each day's melting period is short, so that the pack dissipates very slowly. All streams flowing from the mountains are thus plentifully supplied with natural runoff until far into the dry season of the year, and, with the regulating reservoirs constructed on many of the rivers, a year-round dependable supply is obtained.

Typical of this seasonal distribution of precipitation and snowmelt is the

area in the vicinity of Fresno (Fig. 1). Although only 16 per cent of the annual precipitation at Fresno falls in April-July, 75 per cent of the yearly runoff of the Kings River at Piedra occurs during these months. Irrigation, one of the more directly affected beneficiaries of this time lag, rises sharply in April, reaches a peak during June and July, and tapers off considerably in September.

This annual snow reservoir cannot be controlled by man, but he can foretell to a large degree nature's operation of the reservoir after the period of precipitation has nearly come to a close and the period of snow melt is about to start. An important tool that engineers employ for this purpose is the snow survey.

Organization of Surveys

In the early 1900's J. E. Church of the University of Nevada became interested in forecasting the annual rise of Lake Tahoe from snowpack surrounding the lake. He found that, by cutting vertical cores from the snow mantle according to a predetermined plan, weighing them for water content, and computing an index of snowpack in the basin, he could predict with reasonable accuracy the inflow into the lake. The first snow surveys by the state of California for the purpose of

accurately forecasting runoff were begun in 1918. In cooperation with Nevada, snow surveys were carried on for several years in the watersheds of Lake Tahoe and the Yuba, Carson, and Walker rivers. This work languished after 1923 because of lack of funds.

The present program of snow surveys was initiated in 1929 through the efforts of the California Economic Research Council of the State Chamber of Commerce. From 1929 to 1933 the legislature set aside \$15,000 each year to organize and carry on this work, which was allocated to the Div. of Water Resources of the State Engineer's Office. In 1933 the legislature, in the interests of stringent economy, provided no funds for snow surveying, and during the following 2 years the only work of this nature was performed locally without state assistance. This was an early demonstration of the value cooperating agencies placed on such surveys. In 1935 the program was reestablished as a state function, but with an appropriation only one-half of that formerly provided. With additional assistance from the cooperating agencies, however, the essentials of the program put into effect during 1929-33 were continued.

The "California Cooperative Snow Surveys" are supervised by the state, which handles practically all arrangements with respect to field procedure, to insure correlation and standardization, and aids in building, maintaining, and stocking the mountain shelter cabins. A large proportion of the actual surveys, however, are made by the personnel of the various cooperating organizations, including federal and state agencies, municipalities, utility and irrigation districts, power com-

panies, and private land and canal companies. A total of 38 organizations engage in this work. If each of the national forests and national parks and the widely separated divisions of the larger power companies, operating under different field management, were considered separate agencies, the

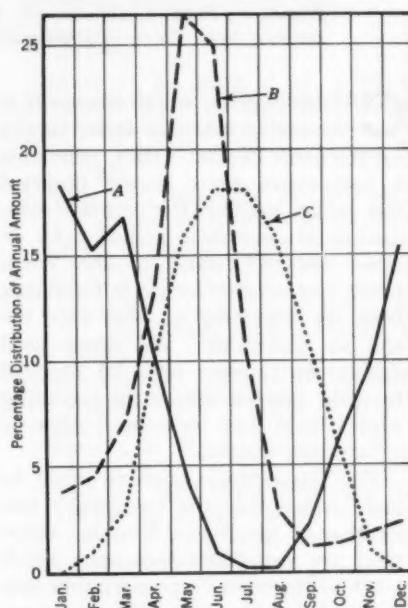


Fig. 1. Precipitation, Runoff, and Irrigation Demand, Fresno Area

A—precipitation at Fresno; B—runoff of Kings River at Piedra; C—irrigation demand in Fresno vicinity.

number of cooperating units would exceed 50.

There are approximately 275 active snowcourses in California. For the main (Apr. 1) snow survey, it is necessary to send more than 150 men into the field in order to complete the work within the allowable time limit. About

one-third of the men are paid by or through the state, and two-thirds are carried directly on the payrolls of the different coooperating agencies, which furnish half of the \$60,000 total annual cost of the operations.

The surveys cover 31 watersheds, from the Shasta River in the north to the Cottonwood Creek Basin in the south. A forecast is made of the runoff of each main stream where it leaves the mountains, and also at several points on the higher tributaries. Reports of water conditions, issued during the first few days of February, March, April, and May of each year, contain complete basic data gathered by the snow surveyors, as well as state-wide information on precipitation, surface reservoir storage, and stream flow. The February and March reports give preliminary forecasts of April-July runoff for main-stem gaging points on the major Sierra Nevada streams, based upon the assumption of both normal and no precipitation during the period from the date of forecast through June. The April report contains forecasts of runoff for the ensuing April-July period for many additional gaging points, together with a review of ground water conditions in the critical areas of the state. The May report comprises forecasts adjusted for observations made during April.

Water Supply Forecasting Techniques

Water supply forecasting methods practiced by the Div. of Water Resources are the subject of continuing research. As each year passes, the data for evaluating the many factors involved in such forecasts become more nearly complete, so that re-

appraisals of former assumptions are possible. The wide extent of the thirteen major watersheds whose runoff is forecast by the division means that physical conditions change greatly from basin to basin—from the lava fields of the north, through the granite watersheds of the center, to the high-elevation semiarid lands of the south. Methods of forecasting are the same in all areas, but the factors important to runoff may differ. Although the contributions of percolating waters are of appreciable magnitude in the lava regions, they are of little significance on the granite watersheds. Soil priming likewise varies in importance, as do many other factors considered in water supply forecasting.

At this point, it should be noted that forecasting as practiced by the California Cooperative Snow Surveys is dependent not only upon the actual surveys but also upon many other sources of data. It is true, however, that, at present, forecasts are limited to the predominantly snow-fed streams and, of necessity, are based largely upon the snow measurements made on Apr. 1.

Typical of the search for added information to improve water supply predictions is the project recently undertaken to provide storage precipitation gages for many of the blind spots of the Sierra where the total precipitation had never before been measured. The project, made possible by the united efforts of the numerous water-using agencies, established 15-ft towers in the rugged mountain area to provide more than 40 storage gages, with ample capacity for the total seasonal precipitation, both snow and rain. It is hoped that the data so gathered will supplement the snow survey infor-

mation and furnish an additional tool for runoff forecasting.

Forecasts of April-July stream flow prepared by the California Cooperative Snow Surveys are based upon the graphical correlation of historical April-July unimpaired runoffs with: [1] the index of snowpack, determined by the Apr. 1 water content measurements; [2] the index of precipitation during Jul. 1-Mar. 31, which indicates

measurements, an index of contributions from ground water in the period of forecast; [2] the unimpaired flow of the river during March (or any other period of the winter season), an index of the amount of contributions from percolating water in transit to the stream through the soil mantle at the time of the Apr. 1 measurement; or [3] the amount of seasonal precipitation prior to the date that snow first

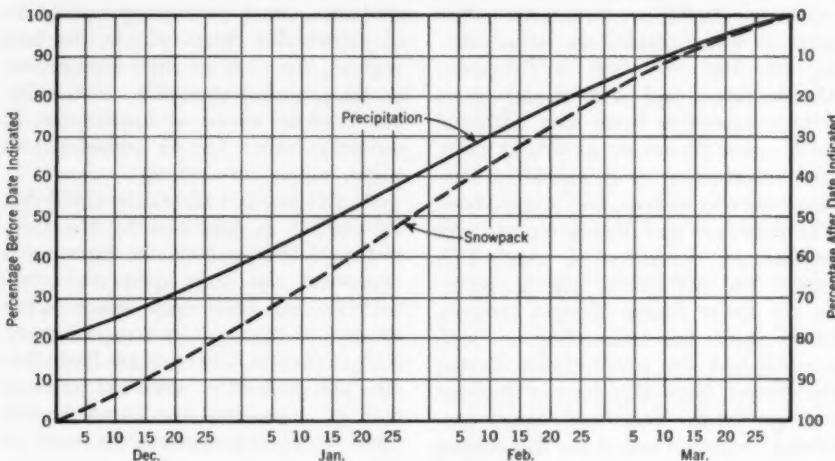


Fig. 2. Time Distribution of Precipitation and Snowpack

These curves, showing normal snowpack deposition and normal Jul. 1-Mar. 31 precipitation distribution over the period from December through March, enable early forecasts to be made.

the degree of soil priming; [3] the index of precipitation during the runoff period; and [4] the previous season's runoff volume, which indicates the degree of carryover from one season to the next.

Refinement of forecasting accuracy is often made possible by considering as an additional variable one of the following: [1] the precipitation during the 2 years prior to the Apr. 1 snow

starts to accumulate on the watershed, an index of the supply of water necessary to satisfy the field requirements of the basin.

The snow surveys made at key stations on Feb. 1 and Mar. 1 are very helpful in the planning work of any water-programming organization. The Apr. 1 forecast may be made at an earlier date if a correction is added to the indexes determined from the snow-

pack and precipitation data available at the time. The percentage values normally expected after the date of measurement determine the amount of correction to be applied (Fig. 2). The chance of variation from normal between the date of measurement and Apr. 1 is greater than the chance of variation between the index of water content determined from the key snowcourses and the index of the entire basin. Therefore, complete sampling of all the snowcourses in the basin is not entirely warranted on Feb. 1 and Mar. 1.

In the interest of economy, a compromise has been made in securing early forecast data by scheduling complete snow survey measurements on Feb. 1 and only partial measurements on Mar. 1. The rationale is that 53 per cent of normal seasonal snowpack can be expected on Feb. 1, 80 per cent on Mar. 1, and 100 per cent on Apr. 1; sampling on Feb. 1, therefore, allows an inventory to be made at the halfway point in the period of normal snow water accretion. On Mar. 1, when an additional 30 per cent of the seasonal snowpack has normally accrued, a partial set of courses is sampled to determine an approximation of snowpack prior to the complete measurements always made on Apr. 1. This program schedule is now in use on the Mokelumne and San Joaquin watersheds.

The envelope curve in Fig. 3 indicates the minimum expectancy of April-July runoff for the Kings River at Piedra, based on the amount of snowpack water content of a key station at Sand Meadow measured at any time during the preceding winter. This graph is an aid in the planning of flood control operations for the Pine Flat Reservoir, recently constructed on

the Kings River, which has a capacity of 1,001,000 acre-ft and is to be used for flood control, irrigation, and, in the future, incidental power. Operation during the winter months will depend upon the policy adopted for the control of rain floods, but, under any policy of operation, if the key snowcourse surveys prior to the Apr. 1

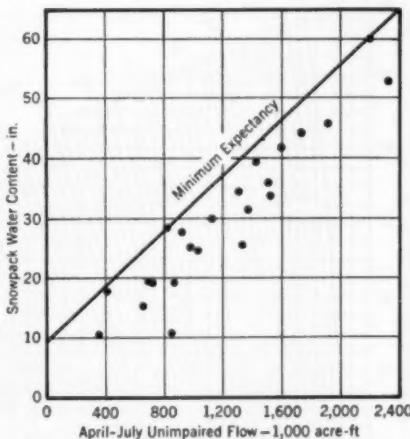


Fig. 3. Minimum Runoff Expectancy, Kings River at Piedra

The curve indicates the minimum amount of runoff that may be expected during April-July for a given snowpack water content as measured at Sand Meadows at any time during the preceding winter. The points show the relation of maximum winter snowpack water content to subsequent April-July flow for the years 1930-52.

forecast indicate that the April-July runoff expectation is greater than the total amount required to fill the reservoir and supply the irrigation demands, releases can be increased to provide additional storage space.

Snow surveying is about to enter the pushbutton era, as an outgrowth of the

recent work of the US Army Corps of Engineers and the US Weather Bureau. It has been found that if a radioactive material (cobalt 60) is put into a cylinder on the ground, the impulse directed to a Geiger-Muller tube placed vertically above it will be diminished by the water content of

content for the sampling point may be found. Although the units are very expensive at present and are subject to mechanical breakdown, they do allow day-to-day checks of snowpack water content to be made. An envelope curve similar to that in Fig. 3 permits immediate use of the data.

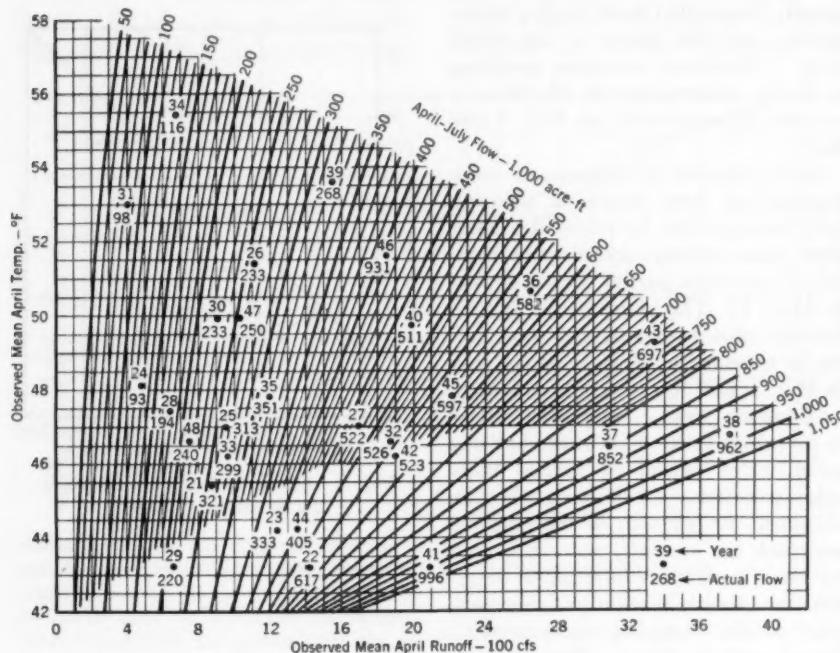


Fig. 4. Temperature-Runoff Diagram, Kern River at Bakersfield

The graph indicates the April-July flow based on the observed April runoff-temperature (at Springville) relationship. This relationship has been plotted for various years (numbers above points), with the actual April-July flow shown by the numbers below the points.

the snow blanket. Radioactive emissions received by the Geiger-Muller tube are broadcast to a mechanical counting device attached to the receiver at the forecaster's desk, and, by the use of a rating curve, the water

When the forecasts of runoff become available, reservoir operation is modified as necessary to control the amount of water predicted for the summer months. In a rather dry year, all the water in excess of downstream needs

is stored. If the amount of water forecast by the snow surveys is more than enough to fill the reservoirs and meet the requirements of downstream use, sufficient storage space must be reserved to limit releases to downstream

and maximum conservation of water will not be accomplished. Conversely, if the forecast is too low, the reservoir will fill too early in the snowmelt season, and a sudden increase in temperature may cause spill from the dam in

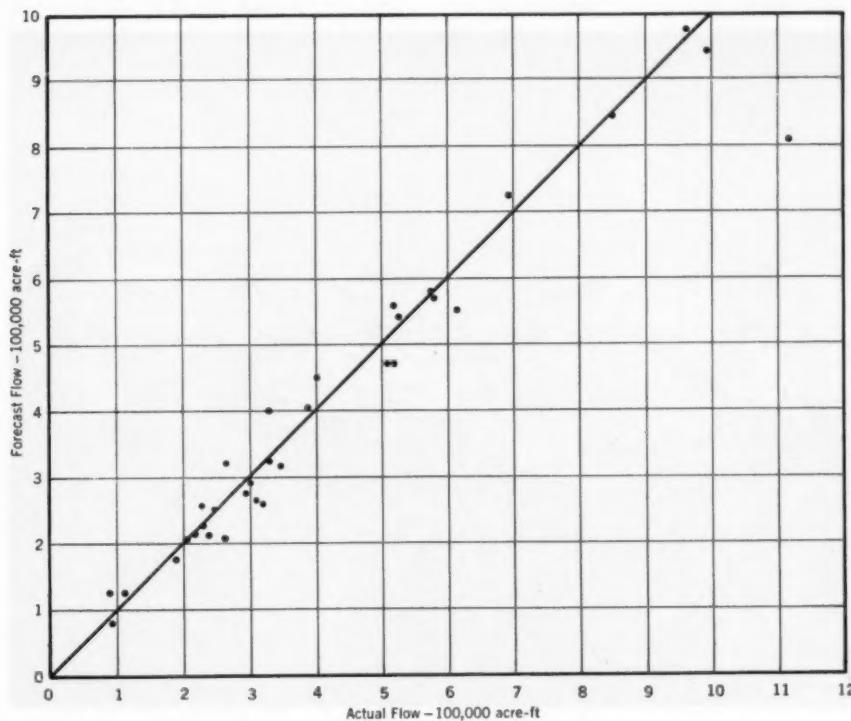


Fig. 5. Forecast Accuracy of Temperature-Runoff Chart

The forecast flow has been plotted against the actual Kern River record flow (at Bakersfield) for the years 1921-52. The proximity of the points to the diagonal line indicates the accuracy of forecasts based on the chart in Fig. 4.

channel capacities. This condition poses the greatest dilemma for the reservoir operator.

Should the runoff forecast be too high and reservoir space needlessly reserved, the reservoir will not be filled

excess of downstream channel capacity. Therefore, data on precipitation and stream flow during the snowmelt period are used to adjust the Apr. 1 forecast on May 1. Temperature-runoff charts, like that in Fig. 4, are

also used for this purpose. (Figure 5 indicates the forecast accuracy of the chart in Fig. 4.)

For a given amount of snow, a given temperature will produce a certain volume of runoff. When the specific temperature produces a value of stream

can be made. It is usually in the period following the issuance of the May 1 forecast that conditions become most difficult for operational planning. The temperature-runoff diagram promises to become another valuable source of information for guiding the planner.



Fig. 6. Heart Lake

Aerial photographs, like this one taken by the Southern California Edison Co., help estimate snowpack distribution in the vicinity of depth markers.

flow greater (or less) than expected, it is probable that the snowpack is greater (or less) than was first assumed. Thus, the operational planner can use this relationship to revise his forecast continually, so that a more accurate prediction of the volume of snowmelt anticipated before Jul. 31

Other projects are being undertaken by the California Cooperative Snow Surveys to help the water programmers. Since 1950 the California Electric Power Co., the Southern California Edison Co., the Div. of Water Resources, and the Los Angeles Dept. of Water and Power have installed

snow depth markers in the higher reaches of the Sierra Nevada, at the sites of many of the more reliable snowcourses, as well as in other areas inaccessible to foot travel during the winter. Aerial photographs of these markers and oblique shots of the general vicinity (Fig. 6) permit areal distribution of snowpack to be estimated. With additional years of record, these photographs should prove of value in indicating phases of snowmelt runoff. Moreover, during the period of snowpack accumulation, the depth markers should enable inexpensive approximations of watershed conditions to be made at dates when surveys on foot are not warranted. The markers will also be of use during drought or flood years, when the import of each individual storm must be evaluated.

Forecasting methods are not necessarily limited to those used by the Div. of Water Resources. The state encourages the division to collaborate with other agencies or individuals in developing improved techniques and accuracy in water supply prediction. Forecasts prepared by different agencies utilizing relationships based on methods other than those of the division afford an excellent opportunity to check the division forecasts prior to release and encourage the competitive spirit that spurs the perfecting of all forecast techniques.

Value of Forecasts

To arrange a program of water use intelligently, it is vital that the control agencies have information on the amount of water at their disposal, and the more in advance of the actual runoff this information is made available, the better their plans can be integrated. The value of forecasts to a particular

agency depends on the character of the water demand. Domestic and irrigation water supply reservoir operators often receive supplemental incomes from hydroelectric plants during the periods when water is released from the dams. In a year of surplus, water can be released for power generation in anticipation of replenishment by subsequent snowmelt. Runoff forecasts allow the programming of releases prior to complete reservoir filling, with resulting increased revenues from power sales, frequently amounting to many times the cost of the snow surveys on the tributary watersheds.

In a year when a shortage of water may occur it is necessary that inventory of available supplies be taken at the earliest opportunity. Measures to provide supplemental water during such periods are always extremely costly and usually must be adopted quickly, to meet an immediate need. The alternative is to curtail the use of water, certainly not a desirable solution even if considered only from the standpoint of revenue. Water supply forecasts will not alleviate shortages, but will allow moderation of the steps taken to relieve them.

To an organization marketing electric power, the early realization of an abundant supply of water means long hours of generation. During an extremely short water year, hydroelectric-power generation may be reserved to take care of peak loads only. Probably the most valuable contribution of snow surveys to the agencies generating electricity is made during the so-called median water years, when power generation can be planned so that only the most efficient steam plants carry the firm load, while the older, less efficient ones are operated

at a minimum, thereby resulting in appreciable savings in fuel costs. Continuous electrical output by the more efficient steam plants permits reservoir storage of water of equivalent potential energy and thus reduces the use of the less efficient plants later in the season.

Crop types and plantings can be varied to fit the available water supply as foretold by snow surveys. The Central Valley of California is an area of diversified farming. Crops with high water requirements can be planted in times of surplus water, with resulting higher income to the farmer. In years of minimum supply, the planting of crops with smaller water requirements may bring the farmer his greatest possible income.

Local problems can be anticipated by the use of water supply forecasts. In a year of flood potential, the volume of runoff that will imperil levees can be foreseen; the number of acres of land in flood control channels, or in areas reclaimed from lakes, that will be inundated by snowmelt runoff can be predicted; releasing a sufficient volume of water from reservoirs early in the season, prior to excessive inflows, may prevent floods later. In a year of short supply, the distance that salt water will encroach into the river deltas or into underground basins may be foretold; the farm acreage that can be profitably planted may be limited; and the power demand for ground water pumping can be anticipated.

Banking and investment houses all avail themselves of the forecast service. Railroads anticipate freight loadings; processing plants foresee their peak loads; and even telephone companies can better forecast the number of long-distance calls that will occur because of the water supply situation. The

forest service anticipates the type of fire season, the lumber company the date that logging roads will be open, the highway department the time to begin opening roads, the resort owner the beginning of the tourist season, and the cattlemen the start and the amount of mountain grazing. To this long list of beneficiaries must be added one more group—the sportsmen. They were quick to realize that water supply forecasts assist in the planning of trips for skiing, fishing, mountain climbing, fast-water canoeing, and many other forms of recreation. Even the release of water from reservoirs for the maintenance of fish life is scheduled from forecasts of water supply.

The reliance that the forecast recipient places upon it is strengthened by demonstrated past accuracy. April 1 forecasts of runoff, predicted for normal weather conditions prevailing throughout the snowmelt period, can ordinarily be expected to be within 10 per cent of actual amounts on those streams where snowmelt is the major source of summer supply. Twenty-four years of data are now available to the water supply forecaster for the weighting of the various factors pertinent to seasonal predictions. As the length of the historical record increases, the variations of weather phenomena can be better evaluated.

Conclusion

Water demand continues to grow, making it increasingly necessary that every drop be used to the greatest possible advantage. The accuracy of water supply forecasts, which aid the advance planning that facilitates most efficient use, must continue to improve in proportion to the growth of demand. New techniques are now available and

others must be found to evaluate supply more accurately. The gathering of each additional year of data makes possible the continued refinement of present forecasting methods.

It is not, however, the promise of greater future accuracy that justifies the water supply forecasting program,

but the proved value of the present service. In California, cooperating agencies now benefiting from the forecasts voluntarily continue to underwrite half the cost of the work. This, in itself, is concrete evidence that the practical value of the program is recognized.

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Portland's New Transmission Line

By Ben S. Morrow

A paper presented on May 26, 1954, at the Annual Conference, Seattle, Wash., by Ben S. Morrow, Engr. & Gen. Mgr., Bureau of Water Works, Portland, Ore.

PORTLAND, Ore., incorporated in 1851, has enjoyed a century of rather steady growth and now has an estimated population of 405,000. It is largely a city of privately owned homes with well kept lawns and gardens, famed for their roses. In 1857 the first public water supply for the city was constructed by two enterprising citizens who installed a wooden pipeline from Caruthers Creek, located about a mile south of what was then the center of town. For the next few years various creeks and wells were added to the system until, in 1868, the Willamette River (Fig. 1) became the main source of supply, the water being pumped at a station located a very short distance from the southern edge of the city.

During low summer flow the Willamette River at Portland is affected by tidal action. Such sewers as had been built discharged into the river, and tidal action rendered the quality of the water at the pumping station very questionable, to say the least. In 1884 the water company built a new pumping station about 5 miles upstream and installed steam-operated pumps with a combined capacity of 16 mgd.

In 1885 the state legislature amended the city charter to authorize Portland to construct or purchase a water supply system sufficient to furnish its residents "an abundant supply of good,

pure water." An engineering study resulted in recommendations for the purchase of certain water rights on the Bull Run River, the construction of a steel pipeline from the Bull Run at a point about 30 miles east of the city, and the building of four distribution reservoirs—two at Mount Tabor and two in City Park—with a combined capacity of 65 mil gal. The water company's facilities were purchased, and the river pumping plant was operated by the city until the completion of the Bull Run line in 1895, the delay being due to the governor's two vetoes of legislation authorizing the issuance of bonds.

The Bull Run River above the diversion for the Portland supply lies almost entirely within a federal forest reserve established in 1892. The watershed, an area of 102 sq miles, is on the west slope of the Cascade Mountains, and the river, with an average runoff of 500 mgd, has its source in innumerable springs, small creeks, and lakes fed by melting snows and rainfall, which is very heavy in this region. Annual precipitation in the city averages about 43 in., while, at the headworks only 30 miles to the east, it is 70 in.; at Bull Run Lake, which is located at the eastern end of the watershed at el 3,160, rainfall averages 144 in. a year.

Bull Run Conduits

Conduit No. 1, completed on Jan. 1, 1895, was designed to carry 25 mgd. It consisted of 24 miles of asphalt-coated, riveted steel pipe varying in diameter from 33 to 42 in. Maintenance on this line, which was in service until the fall of 1953, increased steadily in the past few years, owing to pitting of the steel in the exterior of the pipe.

To meet rising demands for water, Conduit No. 2 was installed in 1911, generally along the same right of way

duits during the summer. In the past the maximum-day demand was approximately twice the daily average, with the peak hourly rate about double the average on the maximum day. Because of the rapidly increasing use of lawn-sprinkling systems, this relationship has changed. At present the peak day's demand is $2\frac{1}{2}$ times the average, and the peak hourly rate is twice the maximum-day average.

In view of the increased demand and the age, small capacity, and heavy maintenance requirements of Conduit

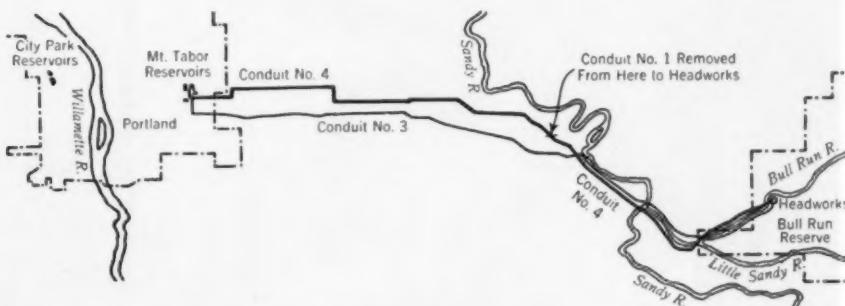


Fig. 1. Bull Run Pipelines

The route of the new conduit (No. 4) is shown.

as the first line. The second steel pipeline, of lock-bar construction and 44-52-in. diameter, had a capacity of 50 mgd and, with Conduit No. 1, provided an adequate supply until 1924. At that time a third steel conduit, 50 and 58 in. in diameter, was laid, to add another 75 mgd.

By 1950 the population of Portland had passed 370,000. The growth of the city, together with the development of suburban areas that had organized 55 water districts or companies supplying 120,000 people, was beginning to tax the capacity of the three con-

No. 1, it was decided to replace it with a new line to carry 100 mgd. Plans called for the installation of 10 miles of 66-in. steel pipe, with a plate thickness of $\frac{3}{8}$ – $\frac{1}{2}$ in., and 15 miles of 56-in. pipe $\frac{5}{16}$ in. thick.

Terrain conditions in the area where the 66-in. portion of the line was to be located made it advisable to remove about 5 miles of Conduit No. 1 and install the new line in its place. As the old conduit had to be kept in service during the summer to meet the heavy demand, the installation of part of the new line had to be delayed. The

major portion of the 56-in. line is located along county roads and is well separated from the other existing conduits, to help assure continuity of service in the event of bombing or other disaster in the area. With only minor deviations, specifications for the new line followed AWWA standards (1). A bid of \$4,975,000, approxi-

tured each pipe length from two 35-ft "cans" composed of two half-sections requiring only two longitudinal welds to the can. A 1½-in. deep bell was rolled in one end of a can, and, after coating and testing, a second can was inserted and the girth seam welded inside and out. This joint was shop tested by air under 40-psi pressure in-



Fig. 2. Pipe Being Laid

Up to 1,540 ft of 56-in. pipe was laid in a day with this equipment.

mately \$275,000 less than the engineers' estimate, was accepted in April 1952.

Fabrication and Coating

The contractor decided to fabricate the pipe in 69-ft 10½-in. lengths and to use mechanical couplings for the field joints. A subcontractor manufac-

tured each pipe length from two 35-ft "cans" composed of two half-sections requiring only two longitudinal welds to the can. A 1½-in. deep bell was rolled in one end of a can, and, after coating and testing, a second can was inserted and the girth seam welded inside and out. This joint was shop tested by air under 40-psi pressure in-

roduced between the two welds, with soap suds indicating any defects in the welding. This method proved very successful in locating leaks, and no trouble was experienced in such joints when the line was subjected to hydrostatic tests.

After the pipe had been thoroughly cleaned by shot blasting and had

passed through a heating oven, it was given a priming coat and the coal-tar enamel coating was spun on. The exterior surface at the ends of each pipe length was left bare for a distance of about 8 in., because mechanical couplings were to be used for the field joints, except for approximately 3,500

accordance with AWWA standards (2). The coated pipe was carefully checked electrically for holidays in the coating, both inside and out, and the percentage of flaws found and repaired was very low.

Angle specials required for changes in alignment or grade were made from



Fig. 3. Coating of Mechanical Couplings

The spray gun is connected by a flexible metal hose, electrically heated, to a trailer-mounted tank in which the enamel coating is prepared.

ft of 66-in. pipe in Sandy River Canyon. There the pipe was belled and the field joints welded. A bonded, coal-tar saturated, asbestos-felt wrap and a whitewash coating were applied to the pipe. Testing, cleaning, blasting, and coating were performed in

segments of tested pipe, the center radius of the bends being four times the pipe diameter and no segment making more than a 15-deg angle. Each angle-welded seam was covered by a butt strap 5 in. in width. The seams of the specials were air tested

and were enameled and wrapped by hand.

Laying of Pipeline

Although trouble had been anticipated in hauling the long sections of pipe over city streets and county roads, none was encountered. The pipe was delivered to the job on specially designed semitrailers.

Practically all of the trench excavation was done with back hoe shovels with $1\frac{1}{2}$ -yd buckets. In the Sandy River Canyon section, however, where grades as high as 76 per cent occur, the trench was dug with a drag line. Bell holes were usually dug with the back hoe as the trench excavation was made, but, in some parts of the line, a truck-mounted crane equipped with a clamshell bucket was used for this purpose. The trench bottom was finely graded by hand just in advance of pipe laying. In sections where rock was found, bedding sand was used.

The pipe was laid by side-boom caterpillar tractors with 5-ton adjustable counterbalances. A spreader bar, 36 ft long, was used to place the pipe in the trench, the pipe being picked up with two 18-in. rubber belting slings (Fig. 2). The maximum amount of pipe laid in one day was 1,540 ft (56-in. diameter).

The mechanical couplings used on approximately 98 per cent of the line had $\frac{7}{16}$ -in. thick T-bar followers, with the middle rings 10 in. long and of the same thickness as the pipe. Steel track head bolts, $\frac{3}{4}$ in., with upset rolled threads, were employed—36 bolts for the 66-in. pipe couplings and 32 for the 56-in. The couplings were primed at the factory.

The coal-tar enamel coating of the couplings was applied by spray equipment designed and patented by the

coating contractor. It consisted of a trailer-mounted rectangular tank of about 3,000-lb capacity, a burner and two butane tanks for heating the enamel, an agitator with a 5-hp motor, a pressure pump with a 7.5-hp motor, and an automatic heat regulator. A 30-ft flexible metal hose carried the enamel to the spray gun. Electricity for the spray machine was furnished by a 440-v a-c diesel generator mounted on the tow truck. The metal hose was heated electrically to about 300°F to keep the enamel from cooling. The enamel in the machine was heated to about 475°F. This system of spraying the enamel on the couplings was a great improvement over the methods used on former jobs. (Figure 3 shows a coupling being sprayed.)

As the pipe was laid, it was back-filled between holes with selected material tamped or water settled to a point above the spring line. Hydrostatic field tests—50 psi above the maximum working pressure and never less than 125 psi—were made, usually on sections 5,000 ft or less in length. Relatively little trouble was experienced.

Although the contract, awarded on Apr. 8, 1952, had a completion date of Jun. 1, 1953, delays due in part to the steel strike in 1952 prevented the line from being completed and put in service until Dec. 18, 1953.

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Design and Operation of Chlorination Stations Under Normal and Emergency Conditions

Panel Discussion

A panel discussion presented on May 24, 1954, at the Annual Conference, Seattle, Wash.

Introduction—H. C. Medbery

A paper presented by H. C. Medbery, Sr. Engr., Water Dept., San Francisco, Calif.

THE evolution of chlorination as a method of disinfecting public water supplies has given the water works man his simplest and perhaps his most effective tool in assuring the consumers a safe supply every day in the year. Furthermore, chlorination is of particular value in maintaining compliance with the US Public Health Service drinking water standards, which are used as a guide by practically all state and local health departments in their control of water utilities.

First successfully employed in this country in 1908, chlorination was thoroughly reviewed in the New Jersey courts because of its adoption as a method of treatment for the Jersey City supply. Expert testimony throughout the trial failed to show any deleterious effects upon either the consumers or the water distribution system, and the process was accepted fairly rapidly by the utilities. Although the early installations employed chlorinated lime, the use of liquid chlorine began, on a plant scale, in 1912 and was soon widely adopted. The commercial high-test hypochlorites did not come into use until about 1928.

In addition to being an effective disinfection process, chlorination is much

utilized in the control of slime, algae (normally in small basins only), and taste and odor, as well as in conjunction with other treatment processes. According to a statistical survey made in 1948 (1), approximately 80 per cent of the population then served by public or private water systems was receiving a chlorinated water, and about 39 per cent was being furnished a water undergoing no treatment other than simple chlorination.

In the Pacific Coast States, where a large percentage of water supplies is derived from surface sources free of appreciable contamination or turbidity, chlorination is of even greater importance than in the nation generally. According to data recently received from state sanitary engineers, 47 per cent of the water supplied by public and private systems in California receives chlorination only; the figure for Oregon is 71 per cent; and, in Washington, it rises to 83 per cent. Consequently, a consideration of chlorination station design factors and operating problems, as well as emergency chlorine supplies, is worth while.

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1. Statistical Summary of Water Supply and Treatment Practices in the United States. *USPHS Pub.*, No. 301 (1953).

Practical Design Factors—Joseph M. Sanchis

A paper presented by Joseph M. Sanchis, San. Engr., Dept. of Water & Power, Los Angeles.

The objective of chlorination station design is to provide facilities that will permit the accomplishment of a particular chlorination task in the most effective, safe, and economical manner. To realize this aim, the designer should not only understand the job to be done and be familiar with the usual physical, chemical, biological, economic, and engineering principles involved, but, more important, he should also have the ability to foresee possible operating problems and be willing to appraise every phase of his design from the operator's viewpoint. This paper will attempt to outline some of the design factors worthy of consideration in the planning of chlorination stations. For convenience in presentation, these factors have been grouped under the following headings: housing, chlorinating equipment, appurtenances, and plant layout.

Housing

Chlorination stations should be located near the point of application, to minimize the length of chlorine solution lines. The site should be well drained and should offer good approaches to facilitate transportation, loading, and unloading of chlorine containers and cylinders under all weather conditions.

Whenever possible, stations with manually operated, automatic start and stop, or program-controlled uniform-feed chlorinating devices are best located above hydraulic grade, in order to reduce back pressure on the injectors. On the other hand, flow-actuated variable-feed automatic machines, which are most effectively controlled by hy-

draulically operated devices governed by pressure-differential meters installed on the line being chlorinated, should be located at a point that will remain below the hydraulic grade line under all conditions of flow. Because operating water pressures must generally be about three times the back pressure on the injector, however, the position of the station should be as little below hydraulic grade as possible, to avoid excessive pumping costs and unnecessarily high operating water pressures.

When topographic or hydraulic conditions are such that flow-actuated variable-feed chlorinating devices must be placed above hydraulic grade, it will be necessary to provide mechanically, electrically, or pneumatically operated auxiliary devices to actuate the chlorine feed mechanism in response to variations in water flow. Although some of these auxiliary devices are capable of high sensitivity and accuracy of control, they have the disadvantage of being actuated by sources of power that are, as a rule, independent of those inducing flow in the water being treated. Because these sources of power are subject to occasional and unforeseeable failures, it is necessary to provide additional automatically operated standby facilities for the auxiliary equipment, thus complicating the operation and maintenance problem.

When pipelines are chlorinated, the point of application should be located downstream from automatically operated valves (such as altitude valves), metering devices, and other appur-

tenances that may produce abrupt changes in back pressure from time to time or suffer damage through continuous exposure to high chlorine concentrations. In the interest of safety, a special effort must be made to avoid locations where the point of application would require a depth much greater than 15 ft from the manhole entrance to the bottom of the pit housing the chlorine injection header.

Structural Considerations

Permanent chlorination stations should be housed in well built, insulated, lighted, ventilated, drained, and fire-resistant one-story buildings. Although such a structure should conform architecturally with its surroundings, the building's appearance should tend to promote pride among the operating personnel and confidence in its mission among water users.

Of particular importance in chlorination stations is the provision of separate exit doors from each room in the building, as well as facilities for safe and easy container loading and unloading, storage, and moving. It is also important to provide adequate angle or channel iron protection for the frames of chlorine container unloading openings and for truck doors, in order to prevent damage to the structure during unloading operations.

Because windows in isolated buildings seem to offer attractive targets for all types of missiles, which may also cause damage to the chlorinating equipment, and because experience indicates that direct sunlight has deleterious effects on equipment parts made of rubber or hard rubber, it has been found advantageous to eliminate all windows from chlorination station buildings and to rely on artificial illumination. The amount of light provided should be

sufficient for comfortably reading all recording and indicating devices and observing the performance of all equipment and appurtenances. Individual lighting should be provided over the log book desk. In order to facilitate the adjustment and repair of equipment parts that are unavoidably shielded from stationary sources of light, it is necessary to provide sufficient electrical outlets so that every point in the station can be reached conveniently with extension cord lamps.

Ideally, the heating facilities provided should be capable of maintaining a uniform, moderate temperature throughout the chlorination station. The elimination of windows provides improved wall insulation and is, therefore, helpful in maintaining uniform building temperatures. Cold spots near chlorine gas lines and chlorinating equipment are particularly objectionable, as they promote liquefaction of the chlorine gas. The presence of liquid chlorine in chlorinating devices not only interferes with their proper performance but also causes damage to the equipment, thus adding to the work of operation and maintenance. Warm air circulation, steam and hot-water radiators, and electric heaters are the devices most commonly used to satisfy heating requirements in chlorination stations.

The room housing chlorine-containing equipment should be made reasonably gastight and should be provided with mechanical ventilating facilities of sufficient capacity to change the air about once every 2 min. Exhaust duct ports should be placed at floor level and as far as possible from outside doors and openings. In populated locations, the duct ports should be part of an exhaust system that terminates

at a point high enough to insure effective atmospheric dilution. In isolated locations, fan type ventilators discharging directly into unoccupied areas have been found highly satisfactory. Air inlets should be located near doors on the opposite side of the room from the exhaust ports. In colder climates, the incoming air should be brought to a suitable temperature before it enters the chlorine room, in order to prevent adverse effects on the operation of the chlorinating equipment. The use of movable louvers—opening and closing by gravity at the inlet and outlet ports as the blowers start and stop—are advantageous in conserving heat and in eliminating drafts when the blowers are not in operation. Switches for ventilating fans should be located within easy reach, at the entrances to the building.

Another important factor to be considered in structural design is drainage, both inside and outside of the chlorination station. Storm waters must be carried away quickly and safely from the vicinity of the station and its approaches. As an additional precaution against flooding, the floor of the station should be placed at least 6 in. above the level of the surrounding ground. The building should also be provided with a well planned system of floor drains, designed to carry away from all depressions any water that may reach the floor during operation or repair. Clean water used in connection with the maintenance of water seals and for other purposes is sometimes bled directly into a protected sump, from which it is automatically boosted by a float-operated pump into the main at a point before chlorination.

Construction economy can be attained through the standardization of building types with such dimensions as

will permit the most effective utilization of readily available, low-cost structural materials and keep trimming, fitting, forming, and other time-consuming operations to a minimum. Standardization also gives the designer a better opportunity to concentrate on the improvement of details and on the judicious selection of economical materials and methods of construction.

Chlorinating Equipment

The capacity and feed range of chlorinating devices must fit the particular requirements of the job to be done—disinfection, color or odor removal, plankton control, and so forth. The factors affecting these requirements are: the maximum, minimum, and average flow of water to be treated; the chlorine demand characteristics of this water; and the amount and type of chlorine residual (free, combined, or total) necessary, after a given contact time, to produce the desired result. As Fig. 1 indicates, the chlorine dosage required may vary greatly from one period to another.

The selection of the type of chlorinating device to be used for a particular task is influenced by such factors as: [1] capacity and chlorine feed range requirements; [2] variability of water flow, which determines whether manual or fully automatic equipment is suitable; [3] availability of water at a pressure adequate for the operation of chlorine injectors—or of power for boosting the pressure—which determines whether direct gas feed or solution feed machines may be used; [4] climatic conditions, such as extremely low temperatures, which may limit the applicability of certain types of equipment; [5] operational economics, such as labor time and chemical costs; and [6] availability of skilled labor and

supervisory personnel, which may have a bearing on decisions between simpler chlorinating devices involving higher operating costs and more economically operated but more complex mechanisms.

Standby chlorinating equipment is essential in stations established for the purpose of water disinfection. In installations requiring one chlorinating device, an additional chlorinator of equal capacity should be provided for emergency situations. In installations requiring more than one chlorinating

and chemical properties to insure long life with freedom from performance failures.

Appurtenances

Every effort should be made to include chlorine container and cylinder handling facilities that will permit safe and convenient manipulation. In stations using 100- or 150-lb cylinders, provision of hoists is usually avoided, to prevent improper and dangerous cylinder lifting practices; magnets, rope or chain slings, or hooks should

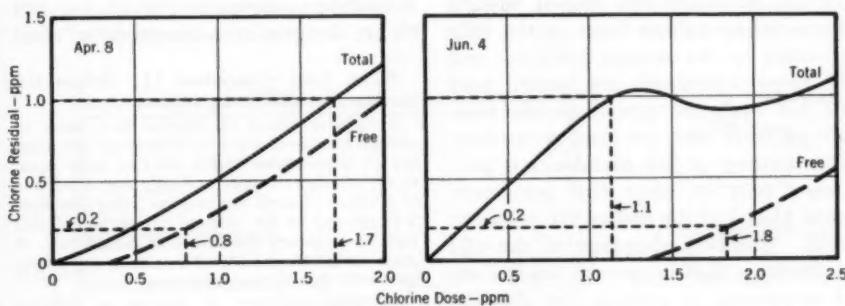


Fig. 1. Variability of Chlorine Demand

Although an 0.8-ppm chlorine dosage was sufficient to produce a 0.2-ppm residual (after a 15-min contact) on Apr. 8, 1953, the same residual required a 1.8-ppm dosage on Jun. 4, 1953.

unit in operation, it is good practice to provide a duplicate of the largest unit in the group as a standby. If the difference in capacity between individual units is great, however, consideration should be given to providing both a large and a small unit for standby purposes.

To safeguard against interruptions in service, the chlorinating equipment selected for water disinfection should be of sound design and, in addition, should be sturdily constructed from materials having the necessary physical

not be used to hoist cylinders by their hoods. Cylinders are best moved about by rolling them on their base while balancing them at an angle or by carrying them, properly balanced and secured, in hand trucks. Scale platforms should be nearly level with the floor, the pedestal of the scale being situated in a well drained recess in the floor. As the cylinders must be stored and used in an upright position, it is necessary to provide suitable guards around them to prevent their accidental fall.

In stations where 1-ton containers are used, the effort and dangers involved in manipulation may be minimized by providing monorail hoisting facilities so that the full containers are made to move forward and downward in a single direction on their way from the transporting vehicle to the storage platform and from the platform to the scales, while the empty containers are made to retrace this line of travel on their way out of the station. In this scheme, which is illustrated in Fig. 2, the containers are kept in a horizontal position at all times. The full containers are unloaded and moved toward the scales by rolling them on the rails provided on the storage platform, and the empty containers are hoisted over the full ones and placed on the storage platform near the loading opening. The hoisting of full containers is necessary only to clear the permanent stops placed at the end of the platform rails. Another advantage of the rail platform is that it permits the rolling of containers to position the chlorine valve properly before they are hoisted to the scales. Thus, the questionable practice of providing rollers on the scale platform cradles for this purpose can be eliminated.

A word of caution is advisable, regarding the design of the I-beams used for the traveling hoist in the monorail system: the beam deflections must remain practically negligible at all points in order to facilitate the horizontal movement of containers.

Storage Space Requirements

In locations where all chlorinating facilities are confined to one point, the "working-inventory" or "maximum-inventory" chlorine storage recommendations of the Joint Committee on Chlorine Supply (1) should be fol-

lowed.* Wherever the water supply facilities are such that chlorination is required at many points in the distribution system, it is often advantageous to receive all the chlorine at a central point, from which deliveries are made by truck to the various stations when needed. In this situation, the minimum storage space provided at stations using chlorine at a rate of less than one-fourth of the connected container capacity per day should be that recommended for "critical inventory." * The container storage platforms used in the window-delivery arrangements shown in Fig. 2, 6a, and 6b are designed to accommodate "criti-

*The Joint Committee (1) defines the various inventories as follows:

Critical inventory of chlorine at a water or sewage treatment plant is defined as the number of unconnected (full) chlorine units equal to the number of units normally connected and in service. Except for systems using less than 5 lb per day or for unusual circumstances, this type of inventory should not be considered. A plant should be considered in emergency operation with this limited inventory.

Working inventory of chlorine at a user's plant may be defined as that inventory which represents a reasonably ample supply to assure continuity of the disinfection treatment. In practice, it should approximate: [1] a duplication of the connected chlorine units (critical inventory); plus [2] a chlorine reserve equivalent to the length of time required for delivery from the shipping point to the user's plant (varies from 2 to 15 days' supply of chlorine, depending on local transportation conditions); plus [3] a chlorine reserve for exigencies (strikes, transportation interruptions, etc.) equivalent to a 15-day supply. The working inventory for any plant must be developed specifically for that plant and be based on actual conditions.

Maximum inventory is defined as that inventory which is equivalent to a 60-day supply of chlorine at the user's plant at normal rates of use. The small users of chlorine (5 lb per day or less) must be excepted from this definition. Beyond the small plant, there are few, if any, practical reasons to exceed the 60-day inventory. To do so ties up an unwarranted stock of cylinders and containers. Maximum inventories should be considered as being temporary only.

cal inventory" plus two containers. The space provided for the extra two containers is normally left unoccupied in order to facilitate loading operations.

Scales

The scales employed are usually of the constant-reading dial or the beam (fulcrum) type, holding one or more cylinders or containers. The scale capacity is determined from the anticipated peak rate of chlorine feed required for the main served and the permissible rate of chlorine gas withdrawal from the containers used. When more than two 1-ton containers have to be placed on a single scale in

Chlorine Gas Lines

As black iron, steel, and copper are unaffected by dry chlorine in the gas or liquid form at ordinary temperatures, they are the most commonly used materials in chlorine gas lines. In stations where one scale is employed, properly valved connections are provided for flexible pipes leading to the chlorine container in service and to an auxiliary container to be used while changing that on the scale. Pressure-reducing valves at the point where the gas enters the chlorine header help to minimize operating difficulties caused by chlorine reliquefaction in the lines. When such valves

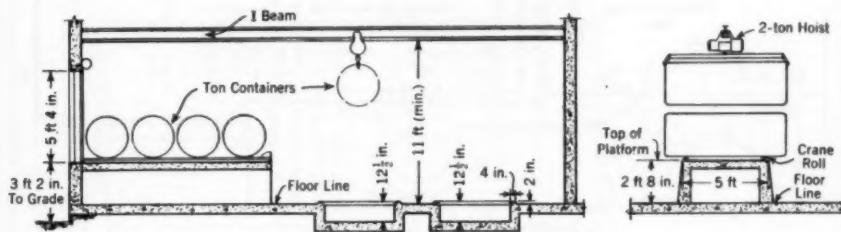


Fig. 2. Chlorine Container Handling Facilities

The containers are kept in a horizontal position at all times.

order to satisfy the chlorine gas feed rate requirements, it is good practice to use liquid chlorine and evaporators.

Scale platforms and fulcrum mechanisms should be protected from the effects of moisture condensation on the cold surfaces of the containers in service and from the occasional spilling of water on the floor. Such safeguards include suitable drip pans under the containers and container cradles on the scales, effective banks to raise the elevation of the scale platforms at least 1 in. above floor level, and ample drainage outlets at the bottom of the scale pits.

are used, suitable bypasses must be provided, with proper valving to permit their occasional inspection and overhaul while the station is in operation. In stations utilizing more than one scale at a time, the chlorine gas header must be designed for maximum flexibility in operation, so that the containers on any of the scales can be used for every chlorinating device (see Fig. 3). As an additional protection against gas reliquefaction difficulties, the entire length of the chlorine gas line should remain in the room where the chlorine-containing equipment is housed, and the horizontal run of pipe

should be placed at the minimum height that will permit proper clearance for interior doorways and operating passages (usually $7\frac{1}{2}$ ft).

When U-shaped chlorine piping arrangements cannot be avoided, an inverted U should be used, to minimize the possibility of liquid chlorine traps at low points. Experience has shown that routing chlorine gas lines through attics or—worse yet—through cold basements, in order to avoid the sight of exposed pipe on the wall, is extremely poor practice.

utilized successfully in chlorine solution lines. A few of the plastic pipes now reaching the market appear to have possibilities for use in moderate back-pressure installations, while rubber-lined steel, "Hastelloy C,"* and some of the more recent plastic-lined pipes, valves, and fittings can be used safely under a wider range of pressure conditions. The chlorine solution headers must be arranged in such a way that, through proper valving, any chlorinating device in the station can be employed on any of the

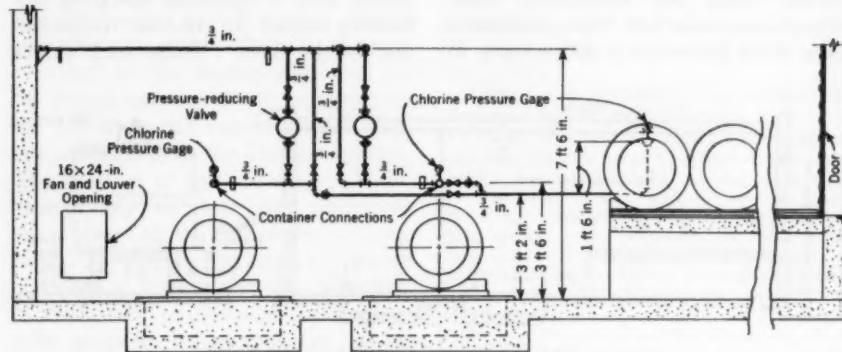


Fig. 3. Chlorine Gas Header

This header is designed for a station provided with two scales and serving two different points of application.

U-shaped arrangements are also to be avoided in piping intended to provide emergency vacuum relief vents for chlorinating equipment.

Chlorine tank type valves should be provided at the point where the container connection is made to the chlorine header and where the chlorinating device is connected to the chlorine gas line.

Chlorine Solution Lines

At low-pressure installations, hard-rubber pipe and rubber hose have been

lines being treated (see Fig. 4). Chlorine solution lines are usually designed for maximum velocities less than 6 fps in order to carry the anticipated peak chlorine solution flows with a reasonable head loss.

The valves most commonly used in chlorine solution lines for high back-pressure installations are of the rubber diaphragm type. For sizes greater than 1 in., flange type valves with

* A high-temperature nickel-base alloy made by Haynes Stellite Co., a division of Union Carbide & Carbon Corp., New York.

rubber- or plastic-lined bodies are popular, while, for sizes of 1 in. or less, screw type valves with "Hastelloy C" bodies are the choice. In low back-pressure installations, hard-rubber or plastic cocks are normally used. All valves should be conveniently located and comfortably reached for ease in operation.

Solution Injection Headers

Solution injection headers should be designed to insure prompt and thorough mixing of the chlorine solution

header to isolate either half of the header and every injection nozzle, in order to prevent interruptions in chlorination while part of the header is out of service.

Chlorine injection headers should be housed in well lighted, ventilated, and drained pits having suitable ladders for safe and rapid exit from any part of the pit in emergencies. Sufficient ceiling clearance should be provided above the main, and the ladders should be arranged to make it possible to go from one side of the main to the other

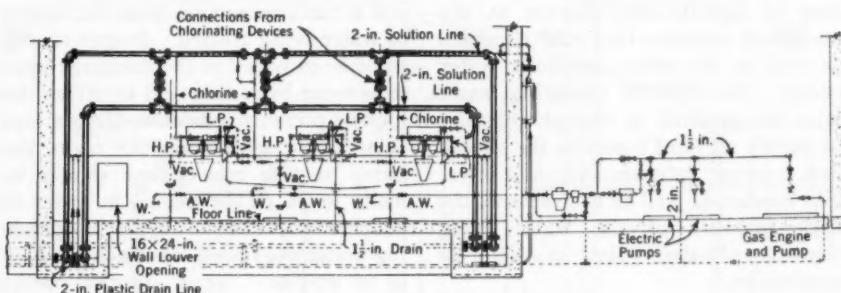


Fig. 4. Chlorine Solution Header

The design of this header is suitable for a station with three chlorinating devices (two in operation and one standby), serving two different points of application. Key to abbreviations: A.W.—auxiliary operating water; H.P.—high-pressure lead from main-line differential water flowmeter; L.P.—low-pressure lead from flowmeter; Vac.—vacuum line; W.—water.

with the water being treated (see Fig. 5). Where public health protection is involved, these headers should be supplied by two independent chlorine solution lines, each capable of delivering maximum flows to all the injection nozzles in the header when the other solution line is out of service for repairs. Likewise, the number of injection nozzles should never be less than two where continuous chlorination is required. Proper valving must also be provided in the chlorine solution

without crawling under it. If the main is so near the surface of the ground that sufficient ceiling clearance cannot be provided, the pit should be covered with removable steel plates to permit access to the upper part of the headers. There should also be ample clearance between the header ring and the walls to allow easy access to any part of the header for inspection or repairs and to facilitate the insertion and removal of injection nozzles. Natural drafts are helpful in keeping the pit

dry and can be easily induced by means of differential-temperature air vents. Ample floor drains should be provided if the pit is located in sloping ground and can be drained by gravity. Where gravity drainage is not feasible, a small water-collecting sump and a float-actuated pump or ejector will keep the floor dry.

Operating-Water Supply Facilities

Where injector solution-feed chlorinating devices are used, it is necessary to provide operating water in sufficient volume and at the proper pressure to operate the injector at the maximum chlorine feed rate required, as well as to satisfy auxiliary water needs. The injector operating water must be supplied at enough pressure to satisfy all head losses in the supply line, injector, solution lines, and injection header, as well as to overcome the back pressure of the water being treated, at the point of chlorine application.

To safeguard against interruption of service where solution-feed devices are used, it is necessary to provide two independent sources of operating water. If the station is to be located at a point where two gravity water supplies with sufficient capacity to satisfy pressure and volume requirements are available, connections should be made to both of them, using adequate checks to prevent short circuiting between the two systems and to obtain the use of the water from whichever source has the higher pressure at any time. If the pressure of the gravity supplies is much greater than that needed for operation, it is good practice to employ pressure-reducing valves (with suitable bypass facilities for emergency use) on the water lines. When only one independent gravity

source of operating water is available, a standby supply must be provided by means of an automatically controlled gasoline-driven pump taking suction from the source of water being treated. If an adequate operating-water supply cannot be obtained from gravity sources, it is good practice to provide two electrically operated pumps, one for service and a duplicate as a standby, in addition to a gasoline-operated pump that automatically goes into operation in the event of power failure. The three pumps should have similar performance characteristics and a common suction from the source of water being treated. Proper checks must be provided in the discharge lines to prevent bypassing and to utilize the highest pressure available. In stations chlorinating more than one main, the pump suction connections should be made to all of the mains, in order to provide a continuous supply of operating water regardless of which of them is in service. Again, proper checks must be installed on all the suction lines to prevent the bypassing of water between mains.

Although both reciprocating and centrifugal pumps have been used successfully to furnish operating water for chlorination purposes, the freedom from pulsations characteristic of centrifugal-pump performance results in better operation of the chlorinating devices.

Automatic Controls

Automatic controls have been found extremely helpful in the operation of chlorination stations. Examples of such devices commonly used in chlorination include: electric start and stop mechanisms, used for the control of uniform-feed chlorinating devices treating the discharge of intermittently

operated pumps; hydraulically, electrically, pneumatically, or mechanically operated converters, used to proportion chlorine feed in accordance with variations in water flow; pressure-actuated electrical devices of the mercury switch type, used to start and stop pumps to satisfy operating-water pressure requirements; and float-operated start and stop electric switches, used to actuate sump pumps or ejectors. In selecting automatic control equipment,

to have data on water and chlorine flows, chlorine pressures and residuals, water pressure in the mains and in the operating-water system, and water temperatures. Because of the permanent character of the information given, recorders are preferable to indicating mechanisms.

Plant Layout

In order to protect costly equipment from damage that may occur through

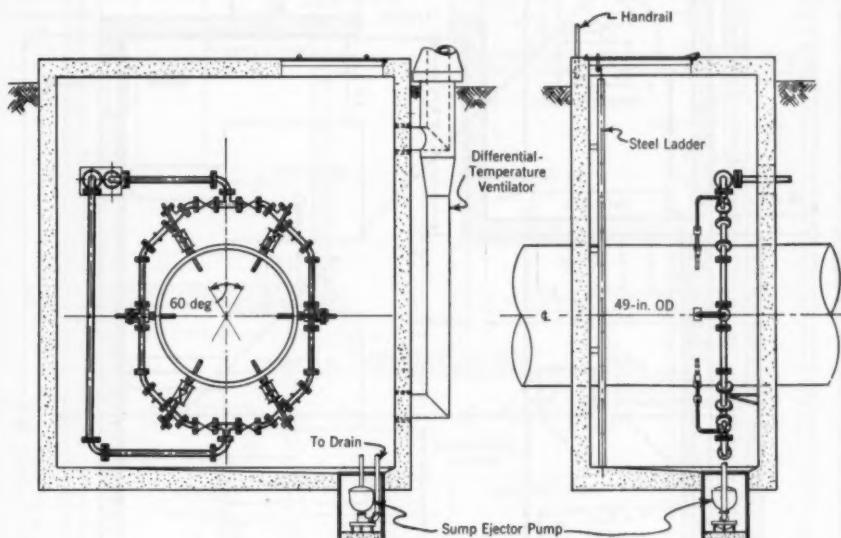


Fig. 5. Chlorine Injection Header

In injection header design, proper attention must be given to lighting, ventilation, drainage, and working clearance.

it should be remembered that the simpler, more direct, and more positive its action, the more satisfactory and reliable will be its performance.

Recording and Indicating Devices

Recording and indicating devices are indispensable guides for effective equipment operation. It is important

accidental exposure to chlorine gas in a moist atmosphere, special efforts should be made to separate the chlorine-containing equipment and pipelines from other equipment, such as recorders, electric motors, switchboards, and so forth (see Fig. 6a and 6b). Sad experiences in stations where this precaution was not observed have

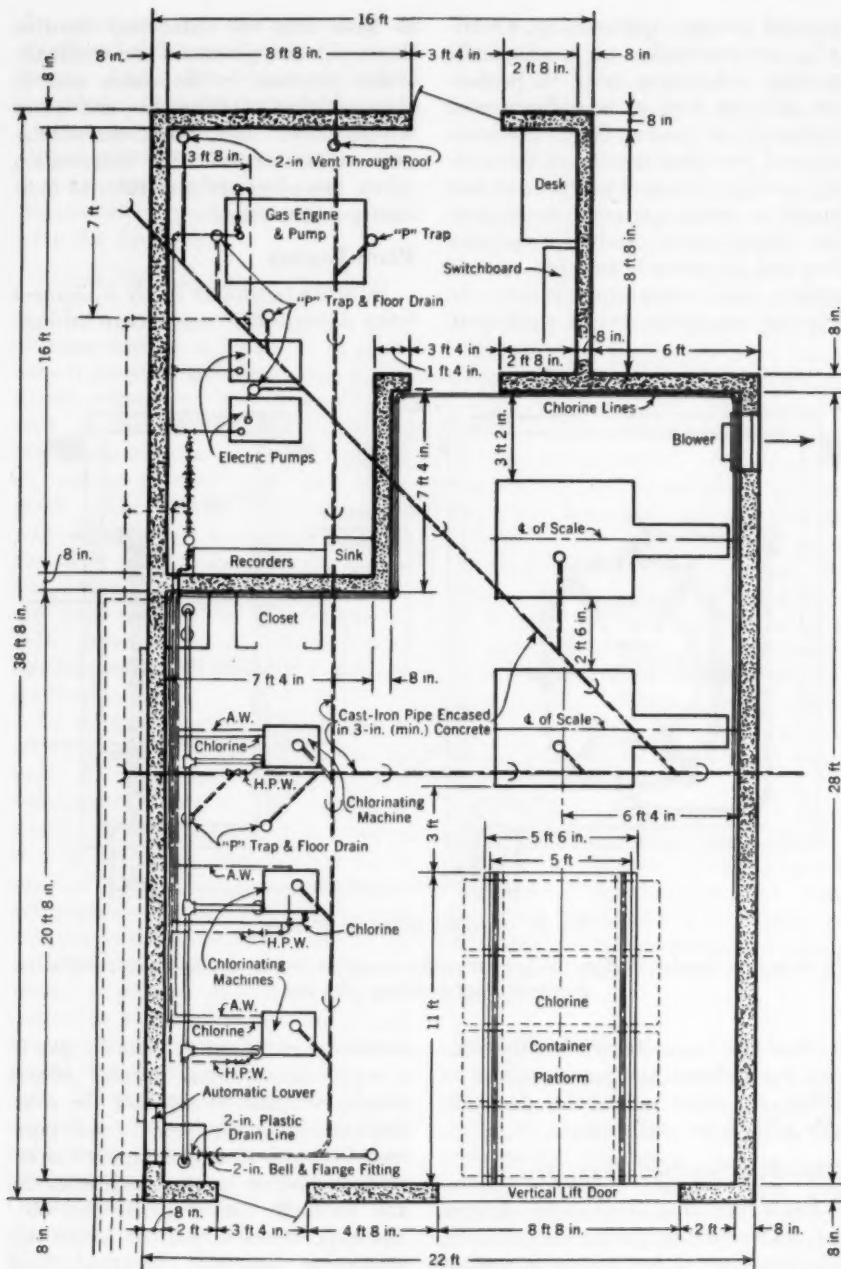


Fig. 6a. Chlorination Station Layout

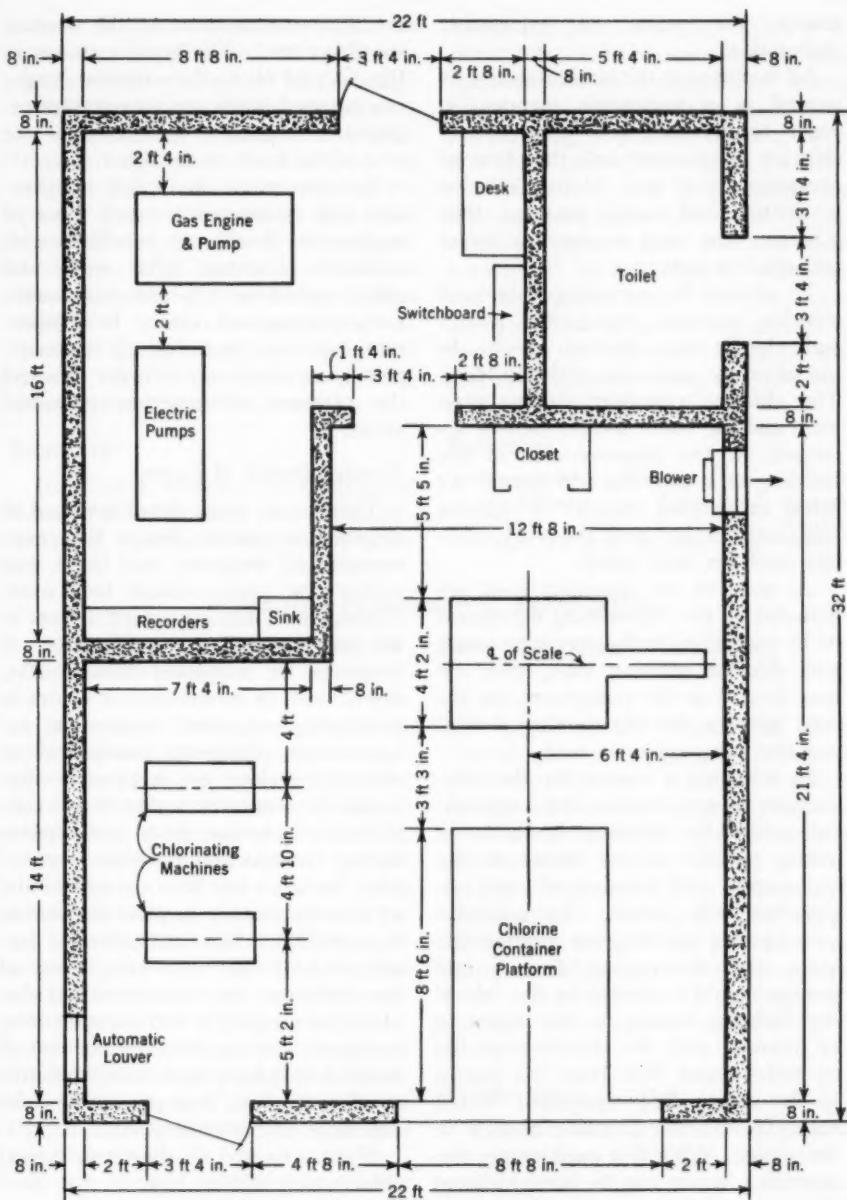


Fig. 6b. Chlorination Station Layout

This design is for the automatic chlorination of one main. Figure 6a (opposite page) is designed for a two-main installation. Key to abbreviations in Fig. 6a: A.W.—auxiliary operating water; H.P.W.—high-pressure operating water.

shown the value of equipment segregation.

All facilities at the station should be located in a systematic manner, in order to maintain the movement of chlorine containers and the flow of operating water and chlorine solution in definite and simple patterns, thus achieving the most economical layout and efficient operation.

To reduce the operating-water and chlorine solution piping, the pumps and chlorinating devices should be placed on the same side of the building. The chlorine container storage platform and the scales should then be arranged on the opposite side of the building in a way that will permit the safest and easiest transfer of chlorine containers to and from the truck, storage platform, and scales.

As most of the recorders used are actuated by the chlorinating equipment or by conditions in the operating-water and chlorine solution lines, they are best located in the pumproom, on the wall between the chlorinating devices and the pumping equipment.

In orienting a station for the chlorination of water mains, the longitudinal axis of the building should be as nearly parallel to the mains as the topography and location of road approaches will permit. To minimize water piping and chlorine solution line costs, the chlorinating devices and pumps should be placed on the side of the building nearest to the mains to be treated, and the direction of the operating-water flow from the pumps to the chlorinating equipment should coincide with the direction of flow in the main. With this positioning, the operating water can be brought from the main to the pumps, made to flow along the wall to the chlorinating equipment, and returned to the mains in chlorine solution form, at the point

of chlorine application, by the shortest possible route. The layouts shown in Fig. 6a and 6b or their mirror images can be used when the topography requires the station to be located on one side of the main or the other.

For convenience and safety in operation and maintenance, every piece of equipment should be provided with sufficient clearance from walls and other equipment to permit easy access for inspection and repair. It is important, however, to utilize all the available space effectively in order to avoid the presence of unnecessary vacant areas.

Standardization of Layout

There is so much detail involved in chlorination station design that even experienced designers, and those who review the plans, cannot help overlooking small but important defects in the design of entirely new layouts. A forgotten or misplaced check valve, drain, vent, or connection, or errors in positioning structural features to accommodate piping or mechanical or electrical devices, are some of the unavoidable occurrences that cause considerable confusion, delay, and expense during construction or—still worse—after the work has been completed and an attempt is made to place the station in operation. Standardization of layout not only aids in averting many of the difficulties just mentioned but also gives the designer a better opportunity to concentrate on the improvement of features that have been found deficient at other stations, thus promoting safer and more efficient operation.

Figures 6a and 6b show two typical chlorination station layouts that have proved successful for medium-size installations. Figure 6b is designed for the automatic chlorination of one main, while Fig. 6a is for a two-main instal-

lation. The two plans are similar in equipment distribution and in dimensions, with the exception of the longitudinal dimensions for the room housing the chlorine containers and chlorinating equipment. Attention is called to the possibility of utilizing the space shown in the upper right-hand corner of the plans for toilet facilities, if needed. The layouts also serve to illustrate some of the design factors considered in this discussion, such as chlorine storage facilities, equipment spacing, ventilation devices, building drainage, and location of exits.

Summary

Installation economy can be attained through simplification and standardization of structural design and plant

layout features, as well as by the judicious selection of equipment, materials, and methods of construction. Economy in operation is made possible by the planning of plant facilities to function safely and effectively with a minimum of effort, and by providing the type of installation that will permit adequate performance with the least amount of labor, chlorine, pumping, and maintenance costs. The best available yardstick for measuring success in design is the extent to which it will make possible successful, safe, and economical operation.

Reference

1. Recommended Procedure in the Use of Chlorine at Water and Sewage Plants. JOINT COMMITTEE REPORT. *Jour. AWWA*, 45:1060 (Oct. 1953).

Operating Problems—*E. Jerry Allen*

A paper presented by E. Jerry Allen, Asst. Supt., Water Dept., Seattle, Wash.

Chlorination station operating problems may be divided into several, somewhat overlapping categories: those related to the type of treatment, such as disinfection, taste and odor control, or slime control; those related to the characteristics of the water being treated; and those related to the physical plant and equipment. This paper will deal essentially with the last group of problems, which are, in large measure, the result of improper design, improper choice of equipment, improper installation of equipment and accessories, or improper application of the fundamental principles of operation and maintenance.

Even though the original design may have been satisfactory with regard to choice of equipment, layout, installation, ventilation, and provision for ample working space, increased water

demands frequently require the chlorination plant to operate in excess of the design capacity. Additional equipment is added or existing facilities are modified to fit current needs; chlorine gas lines and cylinder storage are relocated; larger chlorine containers are adopted; and similar steps are taken. Unless the fundamental principles relating to chlorine and chlorine equipment are adhered to in making such changes, operating problems are likely to arise.

Temperature Control

Chlorine, like any other compressible gas, acts as a refrigerant when expanded from a liquid to a gaseous state or when the pressure is lowered. This means that the chlorine will take heat from its surroundings. Failure to provide the needed heat, or having the air

temperature higher around the chlorine containers than around the piping and chlorine machines, will tend to induce the chlorine to condense back to liquid form or, on occasion, will cause freezing in the gas line, with resulting stoppage. If it is at all possible, the chlorine containers and chlorinating equipment should be housed in separate rooms. The tank room should always be kept at a temperature about 5°F cooler than the machine room. A good working temperature for the tank room is 65°-70°F. At this temperature, the 24-hr rate of chlorine feed can safely be as high as one-fifth the total container capacity. Many of the stoppages of chlorine feed to the machines can be attributed to failure to observe proper temperature control.

Gas Line Stoppages

Frequently the first indication of an operating problem is the awareness that an insufficient dosage of chlorine is being fed. It is well to remember that stoppages often build up gradually. The trouble can usually be traced to the gas line system or the controlling mechanism within the chlorinator.

Stoppages of chlorine gas lines may also be caused by the presence of various oils, lacquer, or pipe coating material. Chlorine reacts with grease and oil to form a luminous, frothy substance; with gasoline and petroleum distillates to form a solid chlorinated hydrocarbon; with ethyl alcohol and ether to form a solid, waxy, hexachlorethane. Any cutting oil or jointing compounds should be cleared completely from the interior of chlorine lines. The safe chlorine equipment cleaners are methane derivatives, chloroform, wood alcohol, and carbon tetrachloride (1).

Stoppages can be caused by the use of improper gaskets; chlorine gas line and tank valve gaskets should preferably be of lead and should never be reused. A pipe material capable of reacting with chlorine may cause not only stoppages but leaks as well. Safe piping for chlorine gas is black iron, copper tubing in the smaller sizes, and hard rubber in the larger sizes of gas piping, but only at low pressures and never where it will come in contact with liquid chlorine. For safety and freedom from leaks, all pipe threads should be of standard taper, not straight running. Joints should be made up with glycerine and litharge cement.

The gas- and air-relief lines leading to the outside atmosphere have frequently caused operating problems due to stoppage. Accumulations of spider webs and insect bodies or mud cases are common sources of stoppage in these lines. Obviously, the remedy is regular inspection and testing.

Chlorine Hydrate

Closely allied with stoppages in chlorine gas lines is the formation of chlorine hydrate, a not infrequent occurrence, but a difficulty that may be easily remedied. The cause is too low a temperature at points where the gas expands and is exposed to water. Chlorine hydrate will form at a temperature of approximately 49°F. Consequently, the temperature should be maintained at 50°F or more, and tray water should have heat available to prevent the formation of chlorine hydrate. The temperature should not, however, be high enough to cause distortion of materials affected by heat. The circulation of the water should be controlled so as to use a minimum amount. Direct-feed chlorinators are occasionally plagued with chlorine hy-

date formation on the diffusers when the water under treatment is at too low a temperature.

Operating Water

A reduction in chlorine feed will occur when the screens on the water supply to the aspirators and injectors become badly fouled with foreign material, such as particles of water weeds, microorganisms, or rust tubercles. The remedy, of course, is frequent inspection to make sure that the screen is intact, together with regular cleaning to prevent serious fouling. It is possible that failure of water pressure reducing and regulating valves will cause stoppage of supply. Such failure can occur by reason of excessive surges or valves that are badly worn. An immediate, though temporary, solution is to replace the regulating and reducing valve with a straight run of pipe until the valve can be repaired. Pressure can be controlled by adjusting the manually operated valve.

Hypochlorinators, although relatively simple—often consisting primarily of a pump with regulated stroke or speed of operation—also have operating problems due to reduced feed of chlorine. Much trouble can usually be traced to the check valves within the machine, as even a small amount of fouling between the check valve and the seat will cause difficulty. The solution being fed must be free of suspended matter to prevent interference with the check valve operation. Occasionally a deposit will build up on the valves, owing to the combination of calcium in some of the hard waters with the hypochlorite.

Automatic Controls

Failure of the automatic control equipment of chlorinators, usually a separate mechanical, electrical, or hy-

draulic device, obviously results in improper feed rates. Proper attention to adjustment, inspection, and correct physical maintenance is the answer to this problem. Every mechanical device is subject to failure and, consequently, is no more dependable than the operator charged with its maintenance.

Good Housekeeping

Cleanliness is of utmost importance in the operation and maintenance of chlorination equipment. Chlorination stations where the equipment is dilapidated in appearance, with rust and corrosion immediately apparent, are almost certain to have operating problems. Good housekeeping is a prime requisite for good operation of a chlorination station. The operator with a clean and attractive station is one who takes pride in the fact that his equipment is functioning properly.

The use of worn, chipped, or damaged parts can often be a source of trouble. It is advisable to maintain a stock of the most frequently needed spare parts, not only to replace worn ones but also to permit parts of proper size and calibration to be inserted to meet variations in rates of feed. A well selected stock will reduce the frequency with which equipment has to be taken out of service for extended periods.

Conclusions and Recommendations

It is strongly recommended that duplicate equipment be maintained wherever possible. At all events, if there is more than one chlorinating machine, the piping layout should permit one machine to be substituted satisfactorily for another until repairs or adjustments are completed.

A program of regular cleaning and overhauling of the chlorine apparatus will go far toward reducing the fre-

quency of operating problems. Properly trained personnel having an understanding of the principles of operation of chlorine-feeding equipment will prevent needless problems and quickly find solutions for those which arise.

Assuming that the chlorination station has been properly designed, that the choice of equipment is appropriate, and that the installation is correct, it

is up to the administrative head to see that his operators take care of this equipment in the proper manner and that fundamental principles and sound safety practices are followed in the handling of chlorine.

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Emergency Chlorine Supplies—*Brian L. Shera*

A paper presented by Brian L. Shera, Mgr., Tech. Services Dept., Pennsylvania Salt Mfg. Co. of Washington, Tacoma, Wash.

Pacific Northwest civil defense planning to cope with a major disaster has included studies on the prevention of infection and disease from disabled water supplies and sanitary facilities. (In this discussion, the term "major disaster" is defined as crippling damage to cities and the industrial complex from hostile military action.) One item of concern to the sanitarians would be the probable disaster damage to water and sewer systems and the severe contamination resulting from it. In addition to physical diversion of sources of contamination, heavy application of chlorine must be considered. Planning ideas were focused toward the potential chlorine and container supply if a major disaster should occur in the Pacific Northwest. The logical sequence of planning leads to the question of chlorine supply in the event that the three chlorine-producing plants in the area are put out of commission by destruction or have to suspend operation owing to lack of electrical power, essential raw materials, or other supplies.

The planning engineers were seeking an estimate of chlorine and container availability, as well as suggestions for meeting the emergency

following a major disaster. The preliminary answers given to the engineers rather dismayed them, as the three chlorine plants in the Pacific Northwest do not customarily store more than a 4-6 days' capacity output. Nor would there be on the premises more than 10 per cent of the several thousand chlorine cylinders and ton containers that these plants own to serve the vast area of Idaho, Montana, Oregon, Washington, and British Columbia. The immediate conclusion, therefore, might be that, if these plants should temporarily cease to operate or be completely destroyed, it would be impossible to obtain an adequate supply of chlorine. The fact that chlorine and containers are not concentrated at the chlorine-manufacturing plants, however, would alleviate an emergency situation in this area. (It is believed that this statement holds true also for other parts of the United States and southern Canada.)

The sanitary chlorine demand in the Pacific Northwest varies seasonally between 120 and 200 tons per month; in a major emergency, the consumption could foreseeably reach a peak of 500 tons per month. It is estimated conservatively that, at any one time,

there would be in storage—at the chlorine-producing plants and at large chlorine consumers' plants (exclusive of water and sewage installations)—and in transit in tank cars, 4,000 tons of chlorine, a large part of which, by emergency directive, could be made available for sanitary purposes. The distribution of this supply is shown in Table 1.

It thus appears that the reserve chlorine supply would meet the sanitary demand for 8 months. This figure might, perhaps, be halved, however, if

TABLE 1
Distribution of Pacific Northwest Chlorine Supplies

| Location | Quantity tons |
|---------------------------------------|------------------|
| Chlorine producers' plants | |
| Tacoma, Wash. | 1,400 |
| Portland, Ore. | 500 |
| Industrial consumers' plants | |
| Lower British Columbia | 150 |
| Northwestern Washington | 550 |
| Southwestern Washington | 630 |
| Western Oregon | 170 |
| Eastern Oregon and Eastern Washington | 50 |
| Idaho and Montana | 150 |
| Tank cars in transit | 400 |
| <i>Total</i> | 4,000 |

biological warfare increased the need for chlorine as a decontaminant. The figure might again be cut in half if the largest reserve supply at chlorine-producing plants were lost. Consequently, even under the most unfortunate and extreme circumstances, the overall chlorine reserve in the Pacific Northwest may be considered sufficient for 2 months. Presumably, also, American ingenuity and fortitude would bring about emergency production of chlorine or find means of transporting it from outside the Pacific Northwest area.

The problem is simplified in that the availability of chlorine by geographical areas is approximately proportional to the population density of those areas. The heaviest population and the chlorine-producing and -consuming industries are located mainly west of the Cascade Range, which divides Western British Columbia, Oregon, and Washington from the remainder of the Pacific Northwest. The possibility that the travel routes through the Cascades, as well as main thoroughfares elsewhere, might be inaccessible or unavailable for chlorine movement will not cause a breakdown of the plan for utilizing emergency chlorine supplies. The map of the Pacific Northwest (Fig. 7) shows that, in the heavily populated areas, chlorine might be available at distances of not more than 60 miles. In sparsely populated areas, less subject to destructive action—Idaho, Montana, eastern Oregon, parts of Washington, and most of British Columbia—the available chlorine supply may be a long distance away, but transportation facilities probably would remain unhampered.

Operational Plan

[NOTE: *The directions which follow are strictly related to emergency conditions and are not intended to be a guide for routine operations.*]

Having determined that a considerable amount of chlorine probably would be available over the area, in tank cars at industrial plants and in transit on rail lines, the problem to be resolved is that of distributing this chlorine to regular sanitary users and to the areas of emergency. In the regular course of events, the sanitary plants have a supply of chlorine and containers that, on the average, represent a reserve sufficient for a week of

normal operation; in addition, there are full and empty containers in transit. In all probability, 90 per cent of the containers are away from the chlorine plants, dispersed throughout the area. The plan suggested is the division of the area into operational districts, each with an expected supply of chlorine and a trained group of sanitarians and

police and fire departments, communication could be maintained to advise users of modifications in the advance plan.

It would not be too difficult to fill cylinders at undamaged industrial plants that have chlorine available in tank cars. A simple system of filling chlorine cylinders from a tank car that



Fig. 7. Estimated Daily Chlorine Inventory

The numbers under the various cities indicate the estimated tonnage of chlorine on hand at other than water and sewerage installations.

industrial-plant chlorine operators who could function to formulate an advance plan to serve in an emergency. The plan would call for all sanitary users within a district to send or bring their empty cylinders to a designated point for refilling from tank cars. By means of radio facilities of the state patrol agencies, sheriff's offices, and city

might be found on a rail siding remote from an industrial area will be described and diagrammed in this paper. It is by no means intended herein to illustrate or describe a chlorine cylinder filling station that would meet any standard except that of emergency service. It is a skeleton installation that could be set up anywhere in a

forest or on a prairie and that a person of mechanical ability and judgment could operate, giving due respect to the dangerous material he is handling.

It should not be inferred that chlorine is easy to meter or apply as a gas without properly designed equipment. In the absence of sufficient chlorine cylinders and adequate application equipment, the delivery and application of chlorine in solution form offers

4,000 gal, the equivalent of 500-1,000 lb of available chlorine. The tank truck could approach the point where chlorine is required, and the solution could be conveyed by a common garden hose to the application point, be it a water flume, pump sump, manhole, or broken sewer. Many tank trucks are equipped with pumps, so that the solution could be sprayed over contaminated buildings or streets. It is

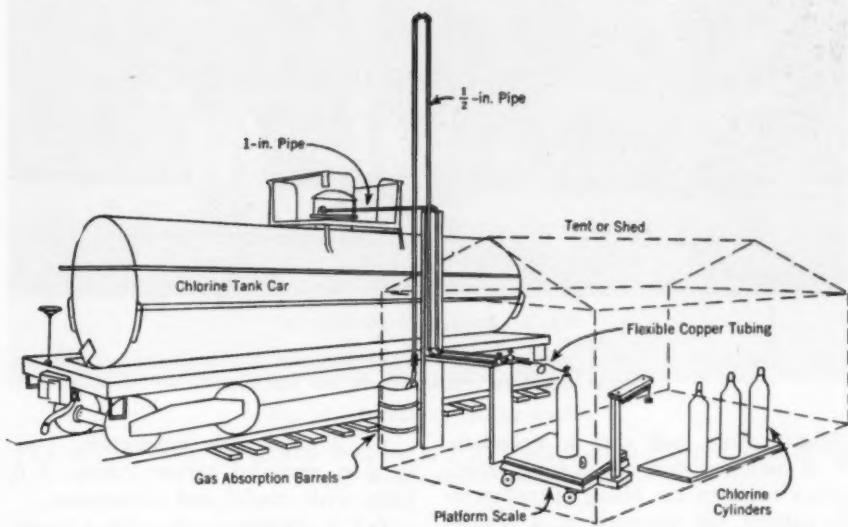


Fig. 8. Emergency Filling Station

Additional details on materials and installation are given in the text and in Fig. 9 and 10.

another possibility. Any of the paper mills that bleach pulp will have chlorine and equipment to make calcium or sodium hypochlorite solutions. These solutions can be transported by tank car or tank truck very satisfactorily. There will be slight corrosion, particularly with sodium hypochlorite, but that condition is of no concern in an emergency. Tank trucks, such as are used for gasoline, could haul 2,000-

true that these measures lack refinement, and, to overcome uncertainty in chlorine dosage, residual analysis should be made or a calculated over-dosage applied. There will be no danger, and complaints under such conditions are hardly to be expected.

Emergency Filling of Cylinders

The diagram in Fig. 8 illustrates an elementary method of transferring

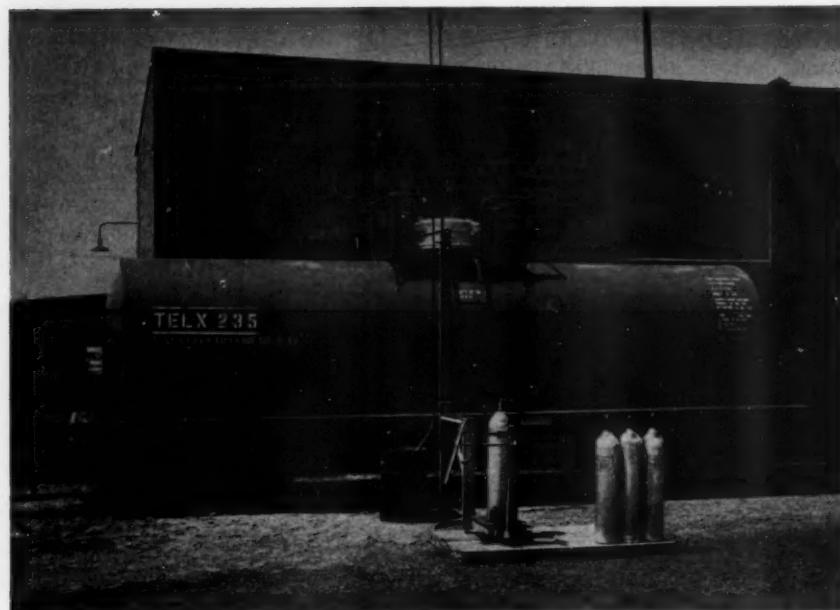


Fig. 9. Emergency Installation

This installation is similar to that shown in the diagram in Fig. 8, except that no shelter has been erected above the platform.

chlorine from tank cars to cylinders. It is assumed that an existing emergency requires the filling operation to be carried out promptly at a remote rail siding with the minimum of equipment. If the operation were being carried out at a chlorine-consuming plant, better equipment would, of course, be available.

Materials

As indicated in the diagram and photographs (Fig. 8-10), the essential equipment consists of:

- (a) 20 ft of 1-in. steel pipe, with fittings
- (b) 20 ft of $\frac{1}{2}$ -in. steel pipe, with fittings
- (c) Two $\frac{1}{2}$ -in. globe valves, or, preferably, $\frac{1}{2}$ -in. ammonia valves

(d) One flexible connection, $\frac{1}{2}$ -in. or $\frac{3}{8}$ -in. annealed copper tubing, 3 ft long, with special end connections

(e) A platform scale, with a capacity of 300 lb for cylinders or 4,000 lb for ton containers

(f) Some form of shelter, a tent, freight shed, or the like.

Installation

1. Install a 15-ft high, rigid post or framework beside the tank car, to support the piping.

2. Insert a 1-in. nipple, 14 in. long, in one of the liquid-chlorine valves. (The two valves on the long axis of the tank car furnish liquid chlorine.)

3. Piping should be installed and supported to avoid strain. Run the



Fig. 10. Details of Filling Station

This closeup of the installation depicted in Fig. 8 and 9 gives a better view of the piping connections required.

piping over to and down the pipe-supporting post to 4 ft above ground level. From there, the pipe should run horizontally into the shelter to the platform scale.

4. Two valves are required, as indicated. The piping is preferably reduced to $\frac{1}{2}$ -in. size, if suitable valves are available. In the absence of chlorine valves, use ammonia or globe valves, which are operable but may need frequent packing changes. Between the two valves, a side outlet is provided.

5. From the side outlet, a flexible connection is needed, to reach the cyl-

inder mounted on the platform scale. This is the only special equipment required and consists of 3 ft of $\frac{3}{8}$ -in. or $\frac{1}{2}$ -in. copper tubing formed into a loop. One end should be slipped into a close-fitting, short pipe nipple and brazed in place. This end is screwed into the chlorine pipe between the valves. The other end has a special fitting that either clamps or threads on the chlorine cylinder valve outlet, which is a $\frac{1}{4}$ -in. straight pipe thread. This fitting may be made from parts of equipment found at a chlorinator installation—for example, a clamp and adaptor or an auxiliary chlorine valve. Such parts

can be cut off, drilled, and brazed on one end of the copper tubing.

6. The chlorine piping following the valves should not be larger than $\frac{1}{2}$ in. It is used to carry away waste chlorine gas in one of three ways: [1] it may be looped upward 20-25 ft and the down leg led into a barrel containing 1 lb of lime per gallon to absorb the gas; [2] if a body of deep water is near by, the pipe or a weighted hose can be led into it; or [3] as a last resort, in unpopulated areas, the gas can be discharged high above or on the lee side of the filling station.

Filling Operation

Compressed-gas cylinders come under interstate transportation regulation and, in some states, under intrastate regulation. Among the many regulations concerning chlorine, one of the most important is that of not overloading the cylinder. In an emergency filling station, with a scale of unknown accuracy on which to base filling weights, the cylinders should be deliberately underfilled by 5 per cent (Table 2).

Inasmuch as the emergency cylinder filling station will lack reconditioning equipment and supplies, only careful visual inspection need be made. The following steps should be taken:

1. Make the piping installation as illustrated in Fig. 8. Apply pipe dope only to the male threads, and tighten the joints well, as chlorine gas can find leaks easily. With all pipe manifolds closed, open the tank car valve momentarily and test piping for leaks. If conditions are satisfactory, open the tank car valve only one turn to charge liquid chlorine into the cylinder filling pipe system.

2. Place the cylinder on the platform scale, and hook up with the flexi-

ble connection to the piping manifold. Release the gas in the cylinder by opening the cylinder valve and the gas-release valve on the pipe manifold. The waste gas should be absorbed in barrels of lime slurry.

3. Note whether the valve stem turns satisfactorily. If it requires excessive force to turn it, loosen the packing nut; remove the packing and the stem; clean the stem and, in the absence of new packing, replace the old packing after having softened it by flexing.

4. Weigh the empty cylinder on the scale and record the amount; add the weight of chlorine to be put into the

TABLE 2
Filling of Cylinders

| Cylinder Capacity lb | Dimensions— <i>in.</i> | | Fill to lb |
|-------------------------|------------------------|--------|---------------|
| | Diam. | Height | |
| 100 (tall) | 8 | 48 | 95 |
| 100 (short) | 10 | 36 | 95 |
| 150 | 10 | 50 | 142 |
| 2,000 | 30 | 84 | 1,900 |

cylinder; and reset the scale reading to the new weight.

5. Open the cylinder valve and the liquid-chlorine valve on the manifold. Liquid chlorine will begin flowing into the cylinder. With the chlorine at low temperature, the cylinder may fill to the predetermined weight, but usually gas has to be released from the cylinder from time to time to permit continued filling. To do this close the liquid-chlorine valve in the pipeline and open the gas-release valve for 2 min; then reverse the valve operation. *Do not fill the cylinder beyond the predetermined weight.*

6. With the cylinder filled, close the cylinder valve; close the liquid-

chlorine pipe manifold valve; release gas to the absorption system; examine the cylinder valve for leakage; finally, put on the cylinder valve cap and the valve protective hood.

Hypochlorite Solution Manufacture

The manufacture and distribution of hypochlorite solutions in time of emergency would not be difficult. In the absence of chlorine gas metering and application equipment, solution feeding would offer a more simple means of chlorination than gas feeding. Pulp mills that use chlorine have hypochlorite-manufacturing facilities. Calcium hypochlorite, however, can be made in any concrete or steel tank equipped with an agitator or pump recirculating system. Lime, which is usually available in most communities, is placed in the tank with water and kept in agitation. Liquid chlorine can be fed through iron pipe directly from the tank car to a point near the bottom of the tank where agitation is taking place. The chlorine flow should be started slowly and then increased to a rate at which it is all absorbed, with none escaping to the air.

The flow is continued until nearly all the free lime has reacted with the chlorine. This condition may be determined by chemical titration, but a simple method is to dip out a sample

of hypochlorite in an open pan or jar. A drop of phenolphthalein solution on the surface will cause a red spot to appear. With an excess of unreacted lime, it will remain for some time. As chlorine is added, the time the red spot remains is lessened. Chlorine addition continues until the red spot flashes for only 3-4 sec and then vanishes, at which time the solution is still stable but contains no excessive amount of free lime.

A hypochlorite solution can be made in a tank truck or tank car itself, if agitation is provided by means of a pump. A suction hose will withdraw the liquid, and the discharge hose can be adjusted so that jetting action will furnish agitation. Chlorine can be run through a pipe submerged in the lime slurry, with the flow adjusted to prevent gas escape. As there is not much depth of liquid for absorption, the operation would be slow, but feasible.

Aluminum or galvanized metal should not be placed in contact with hypochlorite solutions. Steel, iron, stainless steel, and glass- or rubber-lined equipment are all satisfactory for emergency operation.

The solution strength will be stable if made to 30 g per liter or 0.25 lb of available chlorine per gallon. Thus, 1 gal of calcium hypochlorite should contain 0.25 lb of chlorine and either 0.3 lb of hydrated lime or 0.22 lb of quicklime.

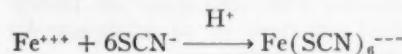
Permanent Spectrophotometer Standard for Iron Determination

By Leonard Aconsky, Taiichi Asami, and Motoko Mori

A contribution to the Journal by Leonard Aconsky, Cpl., US Army; Taiichi Asami, Technical Advisor; and Motoko Mori, Lab. Technician; all of 406th Medical General Lab., US Army, Tokyo, Japan.

THE iron content of water may be determined by the thiocyanate method as described in *Standard Methods* (1). This procedure requires the use of freshly prepared standards or several permanent visual standards for comparison. The technique presented in this paper employs dilute solutions of potassium dichromate ($K_2Cr_2O_7$) as permanent spectrophotometric standards.

According to Schlesinger and Van Valkenburgh (2), ferric ion combines with thiocyanate ions, in acid solution, to form a soluble red complex:



At its optimum wavelength (460 $m\mu$), the iron complex exhibits a linear relation between optical density and concentration on a logarithmic plot. A calibration curve is obtained by a logarithmic plot of the iron concentration against optical density at 460 $m\mu$. The curve is thereafter preset by the use of two dichromate standards which exhibit the same optical properties at 460 $m\mu$ as do the actual iron concentrations.

Reagents and Apparatus

The reagents consist of:

1. Potassium permanganate (0.2N)—dissolve 6.32 g of $KMnO_4$ in dis-

tilled water and dilute to 1 liter. Store the solution in a brown glass bottle.

2. Potassium thiocyanate (2 per cent)—dissolve 20 g of $KSCN$ in a liter of distilled water.

3. Hydrochloric acid (concentrated).

4. Hydrochloric acid (dilute)—dilute 100 ml of concentrated HCl with 300 ml of distilled water.

5. Potassium dichromate (0.1N)—dissolve 4.903 g of $K_2Cr_2O_7$ in distilled water and dilute to 1 liter.

6. Standard iron solution (100 ppm)—dissolve 0.722 g $FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$ (cp) in 50 ml of distilled water and 20 ml of concentrated H_2SO_4 by gentle warming; allow the solution to cool, and add 0.2N $KMnO_4$ until a slight pink color persists; then dilute to 1 liter with distilled water.

The apparatus includes a Coleman Junior Spectrophotometer (Model 6A)* and photometric test tubes, 19 \times 150 mm.

Standardization and Calibration Procedure

Permanent standard tubes A and B: 0.005N and 0.001N solutions are prepared from 0.1N $K_2Cr_2O_7$ solution. These are sealed in spectrophotometer tubes and labeled accordingly.

* A product of Coleman Instruments, Inc., Maywood, Ill.

Calibration. A series of known iron solutions are prepared from the 100-ppm iron standard, and a reagent blank is prepared simultaneously. Place each known solution in 50-ml graduated glass-stoppered cylinders. To each cylinder, add 1 ml dilute HCl, followed by 0.2N KMnO₄. The permanganate is added dropwise until the pink color persists. Shake the contents of each cylinder and allow to stand for 3 min. If the color does not persist, add more KMnO₄. Using distilled water, dilute the contents of each

TABLE 1
Iron Determinations

| Iron Added ppm | Iron Found ppm | Iron Added ppm | Iron Found ppm |
|-------------------|-------------------|-------------------|-------------------|
| 0.06 | 0.06 | 0.26 | 0.28 |
| 0.07 | 0.07 | 0.28 | 0.31 |
| 0.08 | 0.08 | 0.30 | 0.34 |
| 0.09 | 0.06 | 0.50 | 0.56 |
| 0.10 | 0.09 | 1.0 | 1.0 |
| 0.12 | 0.08 | 5.0 | 5.6 |
| 0.14 | 0.14 | 10.0 | 9.7 |
| 0.16 | 0.15 | 20.0 | 19.5 |
| 0.18 | 0.19 | 50.0 | 53 |
| 0.20 | 0.21 | 100 | 93 |
| 0.22 | 0.21 | 1,000 | 985 |
| 0.24 | 0.25 | | |

cylinder to 50 ml. One milliliter of KSCN (2 per cent) is then added, and the contents of each cylinder are thoroughly mixed.

Transfer approximately 10 ml of the contents of each cylinder to a series of spectrophotometer tubes and read the optical density at 460 m μ with the machine preset at zero optical density using the reagent blank. Record the optical densities of the known iron standards, as well as the permanent dichromate standard tubes.

Make a log plot of optical density against the known iron concentration

in parts per million. Plot the points where the optical densities of the *A* and *B* permanent standards intercept the straight-line calibration curve, as in Fig. 5 (see page 897).

Procedure for Unknown

A 100-ml sample of water is used. Add 1.0 ml of concentrated HCl to the sample and evaporate to dryness in a 250-ml beaker. The residue is cooled

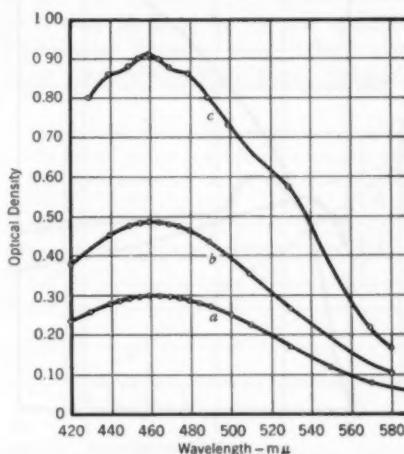


Fig. 1. Spectrophotometric Absorption Curves of Fe(SCN)₅ Complex

Iron content of standard iron solutions: Curve *a*—0.3 mg; Curve *b*—0.6 mg; Curve *c*—1.5 mg. Reagents: 2 ml dilute HCl (1:3), two drops KMnO₄ (0.2N), 2 ml KSCN (2 per cent).

and then dissolved in 1.0 ml of the dilute HCl. Add 10 ml distilled water and warm the solution. Filter the warm solution into a 50-ml graduated glass-stoppered cylinder. Rinse the beaker and filter paper several times with distilled water. Add 0.2N KMnO₄, dropwise, with mixing, until a permanent pink color (which persists after 3 min) is obtained. Dilute the contents

to 50 ml. Add 1.0 ml KSCN (2 per cent) and mix thoroughly.

With the spectrophotometer set at 460 $\text{m}\mu$, the *A* permanent standard is inserted. The galvanometer is adjusted to read the predetermined optical density of the *A* standard, which in

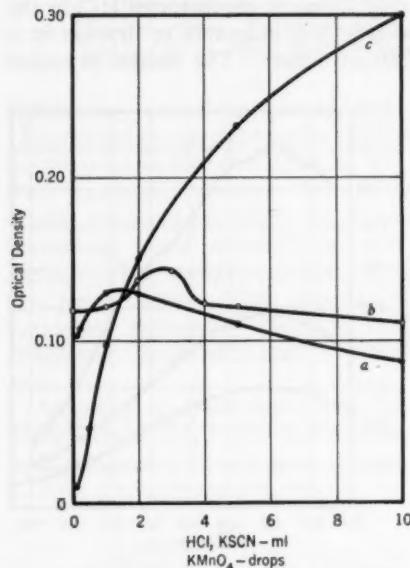


Fig. 2. Effect of Variations in Volume of Reagents on Optical Density

Conditions: standard iron solution (1 mg Fe), 460- $\text{m}\mu$ wavelength, 2 ml dilute HCl, 2 drops KMnO_4 (0.2N), 2 ml KSCN (2 per cent). One reagent was varied for each curve, as follows: Curve a—HCl; Curve b— KMnO_4 ; Curve c—KSCN.

this method is 0.400. When the *B* tube is placed in the machine, it should read the predetermined optical density of the *B* standard, which in this method is 0.083. The instrument is considered set if the *B* tube optical density checks with its known value.

Next transfer a portion of the test solution to a spectrophotometer tube and read the optical density. The iron concentration is then obtained from the calibration curve.

Experimental

The maximum spectrophotometric absorption of the iron complex is at a wavelength of 460 $\text{m}\mu$ (Fig. 1). The effect of differences in the volumes of the various reagents upon the optical

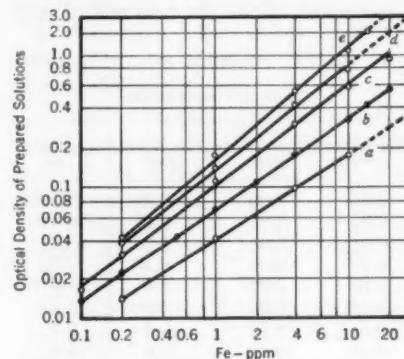


Fig. 3. Optical Density and Iron Concentration

Conditions: 1 ml dilute HCl (1:3), one drop KMnO_4 (0.2N), 460- $\text{m}\mu$ wavelength. Volume of KSCN (2 per cent) varied as follows: Curve a—0.5 ml; Curve b—1 ml; Curve c—2 ml; Curve d—3 ml; Curve e—5 ml.

density of the final test solution is shown graphically in Fig. 2.

Five aliquots of KSCN (2 per cent) were tested (0.5, 1.0, 2.0, 3.0, and 5.0 ml). Figure 3 shows that the points representing the optical-density values of known iron solutions form a straight line on a log plot.

Figure 4 illustrates the relationship between the optical density and the concentration of $\text{K}_2\text{Cr}_2\text{O}_7$. Dilute solu-

tions of $K_2Cr_2O_7$ (0.0002*N* to 0.01*N*) formed a straight line on a log plot when checked at 460 $m\mu$.

The optical density of the $K_2Cr_2O_7$ permanent standards, *A* and *B*, remained unchanged 5 months after sealing. The color stability of the reagent blank and a 1-ppm iron solution was also investigated. It was found that, in 6 hr, the reagent blank showed a change in optical density of only 0.002 units, whereas the 1-ppm iron standard solution showed a change of 0.02 between the 4-hr and 18-hr readings.

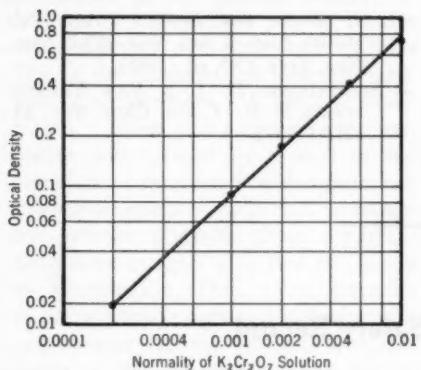


Fig. 4. Optical Density of Potassium Dichromate Solutions

At 460 $m\mu$, the points form a straight line on a log plot.

Table 1 is a summary of iron determinations on known iron solutions. In the range 0.06–0.50 ppm iron, the average deviation was found to be 0.02 ppm. Samples whose iron content was not within the range 0.40–20 ppm were adapted to this procedure by varying the volume of sample used for evaporation or the volume of the final dilution, or both. The iron values were determined from Fig. 5.

Discussion

The employment of permanent spectrophotometric standards has eliminated the necessity of preparing fresh standards for each set of iron determinations. The use of potassium chloroplatinate and cobaltous chloride as standards can be dispensed with by utilizing a spectrophotometer in conjunction with the dichromate standards. The $K_2Cr_2O_7$ permanent standards may be used to set the spectrophotometer because they exhibit the same straight-line logarithmic relation,

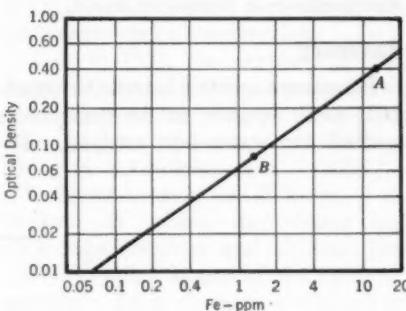


Fig. 5. Optical-Density Calibration Curve

Wavelength, 460 $m\mu$; optical densities of permanent standards are as follows: A—0.400, B—0.083.

at 460 $m\mu$, between optical density and concentration as do the test solutions.

Potassium dichromate solutions were sealed into spectrophotometer tubes by softening the tube tops. The *A* and *B* tubes were read, the machine being set with the reagent blank, at the same time as the temporary standards were read.

It is advisable to take spectrophotometer readings on prepared specimens soon after the KSCN has been added, because the color tends to fade after prolonged standing.

The procedure as described utilizes 1.0 ml KSCN (2 per cent). This volume was chosen to accommodate the range of iron concentrations usually encountered. The use of larger amounts of KSCN will permit the direct reading of lower iron values from a graph similar to Fig. 3. The "best" straight lines, however, were obtained when small volumes of KSCN were used.

The KMnO_4 is used to oxidize any ferrous iron to the ferric state. This oxidation is complete when the pink color of KMnO_4 persists.

When fresh reagents are used, a re-standardization should be made.

Summary

Permanent spectrophotometric standards were adapted to the thiocyanate method for water iron analysis. Di-

lute solutions of $\text{K}_2\text{Cr}_2\text{O}_7$ were found to exhibit an optical density-concentration relationship similar to that of iron in the form of a thiocyanate complex. A log plot of iron concentration against optical density forms a straight line. This relationship can be reestablished each time, using a spectrophotometer set with two sealed $\text{K}_2\text{Cr}_2\text{O}_7$ permanent standards of known optical density. This method is adaptable to all ranges of iron concentrations by slight variations in the procedure.

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1953 Utility Safety Record

The National Safety Council has released statistics on injury rates occurring in 1953 in 40 different industries in the United States. Again, as usual, the communications industry leads all the rest. This most enviable record is being maintained by the application of a sound safety program. The communications industry has found that safety is good business and pays handsome dividends. It can be equally beneficial for water works.

The 1953 injury rates for utilities were as follows:

| Utility | Frequency * | Severity † |
|----------------|-------------|------------|
| Communications | 1.22 | 0.10 |
| Electricity | 9.43 | 1.55 |
| Gas | 12.92 | 0.87 |
| Water | 23.19 | 0.93 |

* Number of lost-time injuries per 1,000,000 man-hours.

† Days lost per 1,000 man-hours.

The rates clearly show that the water industry is a relatively hazardous one in which to work. This condition can readily be improved by carrying on a safety program.

Activities of BDSA Water and Sewerage Division

By **Henry W. Hitzrot**

A paper presented on May 27, 1954, at the Annual Conference, Seattle, Wash., by Henry W. Hitzrot, Director, Water & Sewerage Industry & Utilities Div., Business & Defense Services Administration, US Dept. of Commerce, Washington, D.C.

AT the risk of repeating what perhaps many readers already know, it may be well to review briefly the history and objectives of the Water and Sewerage Industry and Utilities Div. of the Business and Defense Services Administration, US Dept. of Commerce. Three years ago a joint committee was formed by several of the associations interested in domestic and industrial water supply and sewerage and sewage disposal; these organizations were in agreement that an agency in Washington, D.C., was desirable to act as liaison between industry and government for the physical requirements of this comprehensive field. It was recognized that the US Public Health Service was constituted and staffed to serve the many and various public health interests in this same wide field, but that it should not be made incumbent upon the Public Health Service to add to its problems the growing and complex materials, equipment, and statistical requirements and closely related minor services for the construction and operation of water supply and sewage disposal facilities.

Thus, in May 1951, the Water Resources Div. of the National Production Authority (NPA) came into being. It was, in the Korean War

period, primarily a claimant agency for material allotment and priority assistance for equipment for water and sewerage works construction.

Late in 1953, the secretary of commerce abolished NPA and consolidated the important functions of that agency into the new Business and Defense Services Administration (BDSA). The latter consists of 25 industry divisions, of which the Water and Sewerage Industry and Utilities Div. (WSIU Div.) is one of the most important. Each division is headed by a director who comes from industry and serves for 6 months to a year without compensation from the government. Assisting the director are a deputy director and government personnel experienced in their respective fields. The WSIU Div. permanent staff includes: Walter L. Picton, Deputy Director; A. Ted Levie; Henry J. Sullivan; and Mrs. Gwen Benjamin, Secretary. All four are dedicated to the job of serving the interests of the water and sewerage industry.

BDSA Objectives

The objectives of BDSA and its industry divisions can be covered briefly under two general headings: [1] restoring industry's voice in government to a level equal to that of the farmer

and the laborer; and [2] assisting the Office of Defense Mobilization (ODM) with basic information in line with the latter's responsibility for continued programming of adequate mobilization and production for any allout M-Day emergency. As Charles F. Honeywell, BDSA Administrator, puts it, "Our relationship with ODM is equivalent to that of a backfield ball carrier taking signals from the quarterback. They set the policy and tell us what basic information they need for that purpose. We get busy and carry the ball."

To accomplish Objective No. 1, which is purposely rather broadly stated, BDSA looks to members of AWWA and similar associations, through their secretaries and individually, to suggest ways and means of creating new areas wherein they can voice their wishes for governmental action or restraint. To further this objective, the BDSA divisions have set up so-called industry conferences. Usually they take the form of a 1-day meeting of about 25-30 key men from industry with about an equal number of officials of the Dept. of Commerce. There is a carefully planned agenda, allowing ample opportunity for questioning and discussion.

In this connection also, permanent industry advisory committees of 10-15 members, all from the industry or industries represented by a particular BDSA division, are appointed by the administrator and called to Washington, D.C., for meetings as occasion demands. The WSIU Div. is in the process of reactivating its industry advisory committee, possibly somewhat changed in scope and personnel from that existing under the old Water Resources Div. of NPA. It is hoped to

hold a meeting of the new committee in early autumn.

In connection with Objective No. 2—assistance to the Office of Defense Mobilization—assignments can be highly technical and varied. Specifically, expansion goals for mobilization base production frequently involve problems of water and sewerage, one of which is approval of rapid tax amortization programs for these utilities. Recommendations on the individual applications for tax amortization are a definite part of the responsibility of BDSA.

The WSIU Div. is also working closely with all branches of the industry in assisting them to develop adequate pre- and postattack protection measures. This phase of the division's work involves the continuity of production planning which is stressed most emphatically insofar as water supply and sewage disposal are concerned. A "Continuity of Production Task Force" is now being formed and will meet during the summer of 1954 to inform the industry which of the many procedures suggested are best to institute. The question of where the planning and activities of civil defense end and industry takes over to resume production will be clearly defined.

WSIU Division Projects

Having disposed of historical background, objectives, governmental protocol, and committee procedure (the latter very recently acquired and somewhat fraught with confusion), this report will now discuss what the WSIU Div. has done and is doing at its office in Washington. The work done includes:

1. The tabulation and analyses contained in "Water and Sewerage Works

Construction Authorized by NPA in the Calendar Year 1952," a report released in November 1953

2. "Production and Use of Cast-Iron Pressure Pipe and Fittings, 1910-53," a report released in March 1954 and published in the JOURNAL (1)

3. Collaboration with ODM in the revision of estimated requirements for full mobilization

4. A study of the deficiencies in public water supply facilities for defense support

5. The drafting of a tentative standby order for the operation and construction of water and sewerage utilities for use in the event of a national emergency

6. A similar standby order for operation and material allotments for water well drilling

7. Collaboration with the Building Materials and Construction Div. and the Bureau of Labor Statistics in the revision of the estimated value of new construction put in place in 1942-54 for water and sewerage works

8. Collaboration with the Building Materials and Construction Div. in the revision of the annual estimated dollar value of maintenance and repair of water and sewerage works, 1915-53.

A "Survey of the Adequacy of Water Supply," now almost ready for release, will contain useful information on 558 cities of 25,000 population or larger. A data sheet sent out to these cities to verify the information as of the end of 1953 produced a response of 85 per cent, which is exceptionally good and is indicative of great interest. The survey represents the water supply for 80,000,000 people, out of a total of 103,000,000 served by public water supply systems.

Also scheduled for early release are studies and analyses of:

1. "Distribution of Expenditure per Million Dollars for New Construction of Water and Sewerage Works," separately by plant and by system, revised in line with 1952 practice, broken down into labor, principal costs, and principal items of material and equipment

2. "Pipe Use Practice and Trends in Water Works Construction," giving the estimated value of the principal piping material used over the past decade

3. Water and sewerage works included in the advance planning of public works—covering only those on which construction has not yet started—distributed by dollar value of the various categories of construction.

4. The data obtained in the previously mentioned survey on the adequacy of public water supplies, by regions and population groups, with respect to per capita water use

5. Well-drilling activities, 1942-54, including estimated annual dollar value and number of wells, by categories of end use, tonnage of steel casing used, and estimated distribution of the dollar value of new construction, broken down into labor, overhead charges, and principal items of material and equipment.

Later it is expected to develop and release studies on:

1. Estimated historical full value of new construction of water and sewerage works, used to develop the total estimated historical capital investment less obsolescence and depreciation, converted into replacement value in terms of the 1950 dollar.

2. Estimated dollar expenditure of water and sewerage works for mainte-

nance, repair, and operation, 1915-54, with estimated distribution for material, equipment, and labor for maintenance and repair, and other principal items such as fuel, chemicals, power, and administration

3. Other studies of production and use of some of the principal items of water and sewerage works material and equipment, such as valves and hydrants, water meters, and water service fittings.

Among the current services rendered to the water and sewerage industry are:

1. Responses to requests for information on water and sewerage works facilities and operations

2. Guidance to industry representatives for consultation with government officials

3. Participation in the review and revision of federal specifications for water and sewerage works materials and equipment

4. Review of and recommendations on proposed congressional legislation affecting water and sewerage works, with the advice of the technical associations

5. Collaboration with the Bureau of Labor Statistics in a study of accidents in the water works industry

6. Collaboration with the Bureau of the Census in its analysis of data on water use by manufacturing industries, collected in the 1953 Survey of Manufactures

7. Collaboration with the Bureau of the Census on the inclusion of a more detailed list of questions on water use by manufacturing industries in the next complete census of manufactures

8. Collaboration with the Bureau of the Census on a possible revision of the data collected on water and sewerage works for the "Compendium of City Government Finances," in order to increase the value to the water and sewerage works field

9. Participation by recommendation in the identification of water and sewerage works as "essential activities" and the designation of chemists and engineers employed by water and sewerage works as critical occupations for present conditions and, more particularly, in the event of a national emergency.

Members of the water and sewerage industry are urged to send the WSIU Div. any suggestions they may have for division assistance to the industry. The division staff is small in comparison with some of the other BDSA divisions, so that the number of projects it can handle at any one time is limited. Readers are assured, however, that any suggested project that is of benefit to the industry or to an appreciable segment thereof will be carried out somehow.

Reference

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Systematic Analysis of Boiler Deposits

By James W. McCoy

A contribution to the Journal by James W. McCoy, Mfg. Dept., Standard Oil Co. of California, Richmond, Calif.

THIS paper describes a system for the chemical analysis of internal boiler deposits which has been developed over a period of several years and evaluated by trial on approximately 30 different deposits. It has a number of advantages, not the least of them being the rapidity with which a full analysis can be made. Furthermore, the system provides a standard procedure for reporting analyses and a common basis for comparing results on deposits formed at different times and places. Occasional reference is made to the probable combinations of the elements determined, but detailed identification of compounds is beyond the scope of this system. For identifying crystal structures X-ray diffraction analysis is useful, while, to identify all elements that may be present, a spectrographic analysis is necessary.

As it is sometimes difficult to obtain a large sample, provision is made for the determination of iron, aluminum, copper, calcium, magnesium, phos-

phate, and sulfate using a single 1-g sample. Less frequently encountered elements include zinc, manganese, molybdenum, lead, and silver. Because these are seldom present in significant amounts, no detailed procedures have been provided for their determination. Their effect on the other determinations, however, has been noted at appropriate places in the system. If spectrographic equipment is available, the presence of these elements can be easily ascertained before starting the chemical work.

Perhaps the most troublesome feature of a boiler deposit examination is the frequency of phosphate occurrence and the difficulties that it occasions in the separation and determination of the other components. This problem has been solved by the introduction of an ion-exchange step, which provides a rapid separation of phosphate and sulfate from the cations. Sampling is not considered in this paper, because it has been adequately covered elsewhere (1).

Part A—Preliminary Treatment of Laboratory Sample

Internal boiler deposits occur in a variety of forms, and the preliminary handling of the sample will depend upon its condition. Deposits from boiler drums are generally in the form of mud or sludge containing varying

amounts of water. If, upon standing in the sampling container, the sludge settles, leaving supernatant water, the latter should be decanted and discarded. Sludges of this type ordinarily consist of calcium and magne-

sium phosphates, with small quantities of iron and silica. Organic matter may also be present, if a defoaming agent or tannin or lignin treatment is used.

Scales from boiler tubes are usually dry and extremely insoluble; the drying and solvent extractions may be omitted. Such scales may consist of calcium sulfate, silicate, or carbonate; aluminum silicate or oxide; or magnesium silicate; they often contain iron and phosphate in significant amounts. Where demineralized or evaporated feed water is used, internal deposits may consist largely of copper and iron oxide.

Furnace and external tube deposits may contain sodium sulfate and sometimes vanadium, nickel, and iron. The latter are present in some fuel oils and deposit on the outside of the tubes as oxides. The analysis of such deposits is complicated by the difficulty of oxidizing the coke that usually accompanies them and is beyond the scope of this method.

Procedure A

Remove any excess water from the original material by filtration or decantation (Note 1) and discard it. Mix the residue thoroughly with a rod or spatula, and weigh a representative 10-g portion into a tared sintered-glass crucible. Place the crucible in a drying oven at 105°C for 1 hr, cool, and reweigh, noting the loss in weight (Note 2).

Heat 100 ml of petroleum ether to boiling on a steam plate, and pour it through the sintered-glass crucible, using suction (Note 3). Pour an additional 100-ml portion through the crucible and dry by suction. Place

the crucible in the oven for 10 min, cool, and reweigh, noting the loss in weight of the residue (Note 4). Wash the contents of the crucible with 200 ml of boiling benzene; dry by suction and then in the oven for 30 min. Cool and reweigh the crucible, noting the loss in weight of the residue (Note 5). Transfer the residue to a mortar and grind it to a fine powder. A 1-g portion of this material is used for the analysis in Part B (Note 6).

NOTE 1. The amount of water included with a deposit is of no consequence; it is therefore removed and discarded.

NOTE 2. This determination of moisture does not have any significance if excess water was originally present. If the sample was apparently dry initially, the loss in weight is presumed to be the moisture content.

NOTE 3. *Caution should be exercised in handling petroleum ether and benzene as described here; if desired, these extractions can be made in a Soxhlet apparatus.*

NOTE 4. The amount of soluble material is presumed to be the oil content of the sample. It may be reported as "oil" or, more specifically, as "petroleum ether soluble."

NOTE 5. Benzene dissolves oxidized oil and other organic material likely to be present. The loss should be reported as "benzene soluble."

NOTE 6. It is customary in many industrial laboratories to ignite the sample in a muffle furnace at this point, determining and reporting the "loss on ignition." The value of such a figure is questionable, as some elements volatilize, many salts are converted to oxides, the crucible is frequently attacked, and the ignition often renders the ash extremely insoluble, requiring much additional treatment to get it into solution. For these reasons this step is omitted in the system under discussion.

Part B—Analysis of Dry Extracted Residue

Preparation of Solution for Analysis

A 1-g portion of the dried, extracted residue is treated successively with hydrochloric, nitric, and perchloric acids. Hydrochloric acid is used first, because of its powerful solvent effect on the basic oxides that may be present (Fe_2O_3 , Fe_3O_4 , Al_2O_3 , CuO , CaO , and MgO), as well as to dehydrate silicic acid. In any deposit containing organic matter, some carbonaceous material may be left after the solvent extractions. As this must be oxidized before proceeding with the analysis, the sample is next treated with nitric acid until the oxidizing action ceases. Finally, perchloric acid is added and heated to fuming, which serves to oxidize the residual organic matter more or less completely and has the additional advantage of producing a less contaminated silica residue than does hydrochloric or nitric acid alone.

Substances that may fail to dissolve in the acid treatments are magnesium, iron, and aluminum silicates; ignited iron and aluminum oxides; and some forms of silica (native sand, for instance). Phosphates, sulfates, and sulfides will be brought completely into solution by the acid treatment. Iron is seldom found in the first residue in amounts greater than 1-2 mg, unless originally present as silicate; copper, calcium, and phosphate are not found at all. The most likely components are silica, magnesium, and aluminum, as silicates; aluminum as the oxide; and, occasionally, sand.

Of the infrequently occurring elements, silver would remain in the first residue as silver chloride, and lead and molybdenum would separate as lead molybdate if both were present. Mo-

lybdenum alone separates from the acid solution as molybdcic acid; in the presence of phosphate, a clear solution is obtained after dilution. Manganese, usually found in small amounts, is oxidized to manganese dioxide by the fuming perchloric acid, and most of it remains in the residue. These elements are ordinarily present in quantities too small to cause difficulty.

Procedure B1

To a 1-g portion of the dried, extracted residue from Procedure A add 10 ml of 1:1 HCl and evaporate to dryness on a controlled-temperature hot plate (Note 1). Repeat, evaporating to 3 ml. Cool, add 10 ml of HNO_3 , and evaporate to 3 ml. Add 10 ml of HNO_3 (Note 2) and reduce the volume to about 5 ml. If brown fumes continue to be given off, repeat the nitric acid treatment. Cool the solution, add 2 ml of $HClO_4$, and evaporate until this acid fumes (Note 3).

Cool and dilute to 50 ml with water, add 1 g of hydroxylamine hydrochloride ($NH_2OH \cdot HCl$), heat to boiling, and boil for 5 min (Note 4).

Filter through Whatman No. 40' or No. 42 paper (Note 5); wash the residue with three 10-ml portions of dilute HCl (2 ml diluted to 100 ml) and then with three 10-ml portions of water. Treat this residue by Procedure B2.

Dilute the filtrate to 150 ml, and reserve for treatment by Procedure B4.

NOTE 1. The acid digestions are carried out on a controlled-temperature hot plate in order to avoid bumping, provide a slow treatment for maximum solution effect, and minimize loss of phosphate

and sulfate as the corresponding acids. The optimum temperature range is 350°-400°F. If such a hot plate is not available, a steam plate may be used, but the evaporation time will be greatly prolonged.

NOTE 2. If there is no evidence of oxidizing action by the first 10-ml portion of nitric acid, the addition of the second portion may be omitted.

NOTE 3. The perchloric acid should be allowed to fume gently for 2-3 min in order to clear the solution of nitric acid, which has a tendency to attack the ion-exchange resin used in Procedure B4. Strong or excessively long fuming must be avoided, or the phosphate and sulfate losses will be significant.

NOTE 4. Hydroxylamine hydrochloride is added at this point to reduce ferric iron. The principal reason for doing this, as discussed in Procedure B4, is to permit the separation of phosphate and sulfate from the cations in a one-pass ion-exchange operation. The solution must be boiled for at least 5 min to assure complete reduction of ferric iron. For reasons explained in Procedure B4, the acid concentration is kept as low as possible. Consequently, if phosphate and iron are both present in large amounts, as often happens, there may be insufficient hydrogen ion to keep ferric phosphate in solution and the reduction will be even slower. In that event, the ferric phosphate will separate as a voluminous cream-colored precipitate, which reverts to powdery crystals on boiling, gradually dissolving as boiling continues. (It should be noted that some lots of hydroxylamine hydrochloride contain large amounts of sulfate impurity, which will cause erroneous results in the sulfate determination of Procedure B6.)

NOTE 5. If, after the boiling period, the solution is still milky, Al_2O_3 unattacked by the acid treatment is the most likely cause. As it is usually very finely divided, it should be filtered on No.

42 paper; even so, some may pass through, necessitating a second filtration.

Determination of Silica

Silica is determined by the usual volatilization with excess hydrofluoric acid. The method is so well known that no discussion is needed here. A single dehydration has proved adequate for the purposes of this analysis.

Procedure B2

Transfer the residue and filter paper from Procedure B1 to a tared platinum dish and heat it on a hot plate until the paper has dried and charred slightly. Smoke off the paper by heating in a radiator, and then ignite in a muffle furnace at 1,100°C for 30 min. Cool the dish in a desiccator and weigh.

Add 1-2 ml of 1:1 H_2SO_4 to the residue (Note 1) and then about 5 ml of 48 per cent HF, or more if the residue is greater than 0.2 g. Evaporate first on a steam plate, then on a hot plate; finally, muffle at 1,100°C for 30 min. Cool in a desiccator and reweigh, recording the loss in weight as SiO_2 (Note 2).

If there is a residue, treat it by Procedure B3.

NOTE 1. The use of too little H_2SO_4 results in the formation of fluorides instead of sulfates. The former are only slowly converted to oxides, and the residue after ignition will be too heavy—that is, the silica result will be too low. Furthermore, if fluorides of iron and aluminum occur in the residue, both of these elements will be incompletely precipitated in Procedure B7.5, as a result of complex formation, causing low results.

NOTE 2. If magnesium is found later in Procedure B7.5, it may have been present here as MgSO_4 , and the silica loss must be corrected. (See the example given in Part D, page 917.)

Solution of $\text{HF-H}_2\text{SO}_4$ Residue

Some forms of silica—in particular, native sand—are not attacked by hydrofluoric acid and will remain as a residue after the treatment in Procedure B2. In one or two deposits examined, an aluminum-magnesium silicate was found which failed to yield to hydrofluoric acid. Both sand and these silicates are readily opened up in a sodium carbonate fusion. If aluminum oxide is present, it dissolves only to a slight extent in the short fusion described in the following procedure. Because aluminum oxide is practically the only boiler deposit component that would be likely to survive a carbonate fusion, any residue remaining after a second hydrofluoric acid treatment may safely be assumed to be Al_2O_3 , and the weight of the residue may be counted as such. If desired, the residue may be dissolved by fusion with potassium pyrosulfate, reprecipitated, ignited, and weighed. This procedure ordinarily is unnecessary, however, and no detailed description of it will be given.

Magnesium is found in the first residue often enough to make it advisable to provide for its presence (Procedure B7.5). Should no silica be found in the carbonate fusion, then magnesium, if present, will have been weighed as MgSO_4 in Procedure B2, and the silica value must be corrected, as previously mentioned.

Iron is carried down by silicon in an amount less than 2 mg, which, for most purposes, is negligible. If iron is originally present as a silicate, a significant amount may be found in the first residue.

A small amount of manganese is always to be expected and is indicated by a green color in the carbonate fu-

sion resulting from the formation of sodium manganate; the amount is usually too small to be of significance.

Copper, calcium, and phosphate have never been found in this residue, and no provision is made for them.

Procedure B3

Add 1 g of anhydrous sodium carbonate for every 0.1 g of residue (in a platinum dish) and fuse, heating strongly for 10–15 min or longer if the residue seems to be dissolving slowly.

Cool the melt, place the dish in a 250-ml beaker, and cover it with water (Note 1). Slowly add 25 ml of HCl, cover the beaker with a cover glass, and heat on a steam plate until the melt has dissolved. Remove the platinum dish and wash it with water. Evaporate the solution to dryness, add 10 ml of HCl, and again evaporate to dryness (Note 2). Add 5 ml of HCl and 50 ml of water, heat to boiling, and filter through Whatman No. 40 filter paper, washing with dilute HCl and finally with water as in Procedure B1.

Treat the residue as in Procedure B2, adding the weight loss to that recorded therein (Note 3). Reserve the filtrate and washings for treatment under Procedure B7.5.

NOTE 1. If a green color is observed in the carbonate during the fusion or after cooling, it is probably manganate. To avoid attack on the platinum dish, the manganate should be reduced by adding 1–2 ml of alcohol and heating before the HCl is introduced.

NOTE 2. The evaporation of this solution and others in this system is conveniently made by placing the beaker in a "Moroney Solution Evaporator."*

* A product of Fischer Scientific Co., Pittsburgh, Pa.

This device permits rapid evaporation and prevents superheating and consequent bumping. Stirring rods should be removed during evaporation.

NOTE 3. As remarked in the discussion of Procedure B3, any residue remaining after the second HF treatment is almost certainly Al_2O_3 plus a milligram or so of Fe_2O_3 .

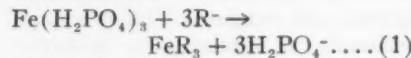
Ion-Exchange Separation

Ion exchange offers a rapid method for the complete separation of phosphate and sulfate from the cations brought into solution by the acid treatment. The operation consists of the following steps: A glass column, equipped with a three-way stopcock and having a sintered-glass plate at the bottom and a flared top, is charged with a strong-acid cation exchanger. The resin is converted to the hydrogen form by treatment with 1:1 hydrochloric acid; the excess acid is washed from the column with water; and, after backwashing once or twice, the column is ready for use. A moderately acid solution of cations and anions is percolated slowly through the column, and hydrogen ions from the resin are exchanged for other cations in the solution. The effluent contains hydrogen ions and the anions originally present, the latter passing unaffected through the column. The cations adsorbed by the resin can then be removed by treating with an excess of acid. This elution step is represented by Reaction 2 below. A suitable column has been described in a previous paper (2).

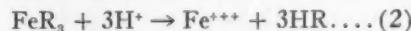
The ion-exchange operation is used in this system only to separate cations from anions. By properly controlling acidity, flow rate, and other conditions, it is possible to make a clean separation of phosphate and sulfate from all of the cations in the solution, with the

exception of H^+ and possibly Na^+ . As economy of time is important in industrial analysis, it is desirable to perform this operation in a single pass through the column.

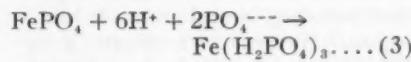
To illustrate several principles used in ion-exchange operations, the separation of phosphate from iron will be discussed in some detail. Several factors must be considered in making use of an ion-exchange separation; among these are acidity, ionic charge, and complex formation. According to Bonner and Romeyn (3), the complex formed between Fe^{+++} and PO_4^{---} in the acid solution is probably $\text{Fe}(\text{H}_2\text{PO}_4)_3$ (un-ionized). As it has no charge, this molecule would presumably pass through a cation-exchange resin column without the adsorption of iron. Because of the high affinity of the resin for ferric ion, however, the following reaction will take place to some extent:



in which R^- indicates the active resin group—sulfonic in this instance. In addition, the concentrations of acid and phosphate will affect the equilibrium. If the acid concentration is high, the reaction favored will be:



If the phosphate concentration is high, considerable acid must be added to the solution to dissolve FePO_4 , as is shown by the following reaction:



A high acid concentration will cause some of the Fe^{+++} to pass through, according to Reaction 2. (This is sometimes called the regenerating effect.)

High phosphate will cause some of the Fe^{+++} to pass through as the neutral molecule, according to Reaction 3. From experimental observation, however, it appears that the effect of Reaction 1 is much greater than that of Reactions 2 and 3; as a consequence, much of the iron can be removed in one pass, and the removal can be made complete by regenerating the resin and repassing the first effluent. This method is undesirable because of the extra time required and because of the large volume of hydrochloric acid used in two elutions, which must subsequently be evaporated. To avoid this double passage, it is possible to take advantage of two properties of the ferrous ion: As the ferrous ion is much less acidic than the ferric, a complete separation of iron from phosphate can be achieved in one pass by first reducing the Fe^{+++} to Fe^{++} . This eliminates the effect of Reaction 3, for no phosphate complex is formed with Fe^{++} . The effect of Reaction 2 is minimized, because much less acid is required to keep ferrous phosphate in solution. In addition, the subsequent elution of the ferrous ion is easier because of its smaller charge.

It should be remarked that some resins exhibit the phenomenon of "color throw" when treated with acids. Amberlite IR-100, in particular, and IR-120, to a lesser extent, show a yellow color similar to that of chloride solutions of ferric iron. This color, caused by small amounts of the resin dissolved in the acid, often disappears after a resin has been used a number of times. The acid treatment described in Procedure B4 is sufficient to remove all cations from the column, and any yellow color in the last portion of acid may be disregarded.

It is important to realize that this organic material consumes permanganate; therefore, iron cannot be determined directly in the effluent. It is of interest to note that the color from some resins behaves as an acid-base indicator, being yellow in acid and colorless in alkaline solution.

Procedure B4

B4.1. Preparation of ion-exchange column. Fill the narrow portion of the special column with water; then add resin (Note 1) until the top of the resin column reaches the flared portion of the tube. Drain the water to the top of the resin column (Note 2), add two successive 25-ml portions of 1:1 HCl, and allow each portion to percolate through the column until the surface of the acid reaches the top of the resin. Wash the column with 150-200 ml of water, added in 25-ml portions. Backwash the column (Note 3) by passing distilled water up through the resin, making certain that no air bubbles are introduced. Drain the water to the top of the resin. The column is then ready to use.

B4.2. Adsorption of cations. Pour the solution obtained in Procedure B1 through the prepared column at the rate of one drop per second, receiving the effluent in a 250-ml volumetric flask (Note 4). Wash the column with sufficient water, added in small portions, to make up the volume. Reserve the solution for use in Procedures B5 and B6.

B4.3. Elution of cations. Elute the cations from the column by alternate treatments (Note 5) with 10-ml portions of 1:1 HCl and water, continuing until 100 ml of each has been added and collecting the effluent in a 400-ml beaker. Finally wash the column with

three 25-ml portions of water, collecting these washings with the main portion of elutriate in the beaker. Backwash the column once or twice. It is once again ready for use.

Add 5 ml of HNO_3 to the beaker, place it in a "Moroney Evaporator," and evaporate the solution almost to dryness (Note 6). Reserve the moist residue for treatment in Procedure B7.1.

NOTE 1. Suitable resins for this operation are Amberlite IR-120,* Amberlite IR-100,* Nalcite MX,† Dowex 50,‡ Permutit Q,§ and, in general, any strong-acid ion-exchange resin. Developmental work for this system was done using Amberlite IR-120 and Permutit Q.

NOTE 2. The solution level must not be allowed to fall below the top of the resin, because air pockets and channeling will result. Should this happen, the resin column can be realigned by backwashing.

NOTE 3. During the acid treatment the volume of the resin will decrease greatly; upon treatment with water it swells, packing tightly in the tube with concomitant slowing of the flow rate. To loosen the column, it is backwashed so that the proper flow rate can be maintained.

NOTE 4. As it is desired to determine both phosphate and sulfate in the sample, the effluent from the column is received in a volumetric flask and aliquots are used. This is necessary even if phosphate alone is to be determined, because most boiler deposits, excepting hard scales, contain so much phosphate that a 1-g sample is too large for the alkalimetric procedure.

NOTE 5. It has been found experimentally that a better recovery of cations from the resin is possible if the eluting acid is added in small portions alternately with water.

NOTE 6. During the exchange step the excess hydroxylamine hydrochloride is retained by the resin and is eluted by the hydrochloric acid along with the metallic cations. This excess must be destroyed before precipitating iron and aluminum, or much of the iron will remain in the ferrous state and fail to precipitate as basic succinate. The nitric acid is added to oxidize $\text{NH}_2\text{OH} \cdot \text{HCl}$ and ferrous ion. The solution is evaporated almost to dryness to destroy the organic matter from the resin, which also retains iron in solution, probably in a manner analogous to complex formation.

Determination of Phosphate

Phosphate is determined in an aliquot of the solution from the ion-exchange separation by the alkalimetric ammonium phosphomolybdate procedure. This method is so well known that no discussion is necessary. The molybdate reagent is prepared as described by Hillebrand and colleagues (4).

Procedure B5

Transfer an aliquot (Note 1) of the solution obtained in Procedure B4.2 to a 400-ml beaker, add two or three small crystals of potassium permanganate, and heat until they dissolve. If the violet color disappears, add more crystals until a permanent color is obtained. Add to the solution 25 ml of nitric acid and 25 ml of 60 per cent ammonium nitrate solution, and dilute to 100 ml. Adjust the temperature of the solution to about 45°C and add 150 ml of molybdate reagent. Mix well by stirring, and allow to stand until the precipitate has settled and the supernatant liquid is clear (10–30 min).

Filter through Whatman No. 7 filter paper, and wash the beaker and precipitate with eight or ten 10-ml portions of 1 per cent KNO_3 solution

* Rohm & Haas Co., Philadelphia.

† National Aluminate Corp., Chicago.

‡ Dow Chemical Co., Midland, Mich.

§ Permutit Co., New York.

(Note 2). Transfer the paper and precipitate to the original precipitation beaker, add 100 ml of water and a measured excess of standard 0.5*N* sodium hydroxide, and dissolve the precipitate by stirring. After complete solution of the precipitate, add a few drops of phenolphthalein indicator and titrate the excess alkali with standard 0.5*N* hydrochloric acid. Record the volumes and normalities of the two solutions, and calculate the percentage of phosphate in the sample (Note 3).

NOTE 1. The size of the aliquot will depend upon the percentage of phosphate; for soft deposits, 25 ml is suitable.

NOTE 2. Unless the precipitate is exceptionally voluminous, eight or ten 10-ml washes will remove the excess acid. The precipitate has a pronounced tendency to "creep"; this may be prevented by adding a drop of "Aerosol" * to the wash solution.

NOTE 3. If the amount of precipitate is small, 0.1*N* reagents should be used. The phosphate result is usually slightly low on account of volatilization during the acid treatment in Procedure B1. If a more accurate result is required, it is best to make a direct determination on a small portion of the dried, extracted residue from Procedure A.

Determination of Sulfate

The determination of sulfate in the presence of phosphate by precipitation as barium sulfate usually produces high results. On investigating several schemes that were reported to improve the determination, it was found that the best results were obtained by precipitation in the usual way from a dilute acid solution. Results, as a rule, were high by 0.5–2 per cent, depending upon the amounts of phosphate and sulfate.

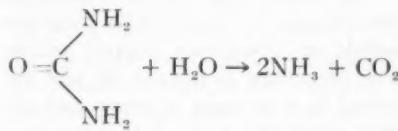
* A product of Am. Cyanamid Co., New York.

Procedure B6

Transfer a 100-ml aliquot of the solution obtained in Procedure B4.2 to a 400-ml beaker, add 4–5 drops of HCl, dilute to 250 ml, and heat to boiling. Precipitate barium sulfate from the boiling solution by dropwise addition of a 10 per cent solution of barium chloride. Digest the solution for 2 hr on a steam plate, and then cool to room temperature. Filter through Whatman No. 42 paper; wash with water; and ignite the paper and precipitate for 1 hr at 1,100°C. From the weight of BaSO₄ obtained, calculate the percentage of sulfate in the sample.

Determination of Cations

This section describes methods for separating and determining the five metallic ions commonly present in boiler deposits: iron, aluminum, copper, calcium, and magnesium. The iron and aluminum that were brought into solution in Procedure B1 are precipitated as basic succinates by homogeneously raising the pH of the solution through the slow hydrolysis of urea (5):



The usual method of precipitating iron and aluminum with ammonium hydroxide is not used for several reasons: the gelatinous precipitate so obtained is difficult to wash; filtration is usually prolonged, even with moderate amounts of aluminum, as a result of clogged filter paper; and the hydrous oxides obtained must be heated excessively long at high temperature to reach constant weight.

The basic succinate procedure has several advantages: a dense, easily filtrable precipitate is obtained; the slow hydrolysis of urea in the boiling solution results in a gradual increase of pH in a homogeneous solution; and a low final pH (4.2-4.6) is obtained, resulting in cleaner separations from the bivalent elements. Because many deposits contain high percentages of iron, the compact form of the resulting precipitate is distinctly preferable to that obtained with ammonia. The ammonia separation is, in general, very poor, owing to the tremendous surface development of the precipitate and the resulting coprecipitation. The details of the basic succinate precipitation are given under Procedure B7.1.

The precipitate containing iron and aluminum is ignited to the oxide form and weighed. The residue is fused with potassium pyrosulfate, and the weight of iron oxide is determined by the Zimmermann-Reinhardt (4) method. This figure is subtracted from the weight of the mixed oxides to determine the weight of aluminum oxide.

The filtrate from the basic succinate precipitation is treated with hydrogen sulfide to precipitate copper sulfide. The precipitate is filtered off and dissolved in a mixture of nitric and sulfuric acids; the acid solution is evaporated to dryness; and copper is determined iodometrically as described in Procedure B7.2.

Hydrogen sulfide is boiled out of the filtrate; the solution is diluted in a volumetric flask; and aliquots are taken for the determination of calcium and magnesium. As calcium and magnesium are major components of internal boiler deposits, aliquots must be

used to obtain suitable amounts of precipitates in the two determinations.

In the usual hydroxyquinoline determination, calcium is first removed as the oxalate and magnesium is precipitated from the filtrate. This method was rejected because the solution at that stage contains so much salt (ammonium chloride, ammonium succinate, ammonium oxalate, and urea) that the excess reagent is thrown out of solution and seriously contaminates the magnesium precipitate. A further disadvantage is the retardation of precipitation resulting from the formation of the magnesium oxalate complex. Consequently, a different method is used. An aliquot of the filtrate from the copper sulfide precipitation is made alkaline to phenolphthalein and treated with an acetic acid solution of 8-hydroxyquinoline ("oxine"). This precipitate is contaminated with excess reagent and must be filtered, washed, dissolved, and reprecipitated. It is also necessary to select an aliquot size that will yield a precipitate weighing not more than 150 mg. This condition is important, as heavier precipitates are always contaminated and yield high results. The second precipitation is made from acetic acid solution to minimize coprecipitation. Magnesium oxide can then be computed (Procedure B7.3).

Calcium is precipitated with oxalate from another aliquot and determined permanganimetrically (Procedure B7.4).

Procedure B7.5 covers the determination of aluminum and magnesium not brought into solution by the original acid treatment. Magnesium is not often found in the first residue, but it occurs occasionally and the aluminum filtrate should be examined for it. It

should be remarked that the amount of aluminum found there will never be very large if it occurred originally as aluminum oxide. The sodium carbonate fusion described in Procedure B3 is not prolonged enough to effect solution of more than a few milligrams of ignited Al_2O_3 . If the aluminum (or magnesium) occurs as silicate, all of it will be brought into solution and a corresponding amount of silicic acid will separate during the evaporation with hydrochloric acid. From these observations and others during the course of the analysis, conclusions about the chemical form of the original deposit can be drawn.

Procedure B7

B7.1. *Iron and aluminum.* To the moist residue obtained in Procedure B4.3 add 5 ml of hydrochloric acid, and dilute to 200 ml with water. Add 5 g of succinic acid, heat to boiling, and neutralize carefully with ammonium hydroxide until a *faint* permanent turbidity or opalescence is produced. To the boiling solution add 5 g of urea, dissolved in a little water; place a small piece of filter paper under a stirring rod in the beaker to promote even boiling; and boil gently for 90 min (Note 1). Water should be added from time to time during the boiling period, so that the final volume is about 150 ml.

At the end of the boiling period remove the beaker from the heat, and filter the hot solution through Whatman No. 41 paper, washing the precipitate with a 1 per cent solution of succinic acid made neutral to methyl red with ammonium hydroxide. Treat the combined filtrate and washings by Procedure B7.2.

A layer of basic succinates that often adheres to the beaker is dissolved in 2 ml of hydrochloric acid, diluted to 50 ml, heated to boiling, and neutralized to methyl red with ammonium hydroxide (Note 2). Allow 2-3 min for the precipitate to flocculate, and filter through Whatman No. 41 paper, washing with the same solution as above. Discard the filtrate and washings.

Combine the two filters containing the precipitates in a tared porcelain crucible (Note 3), dry, char, and ignite for 1 hr at 1,100°C. Cool and reweigh, recording the weight of Fe_2O_3 plus Al_2O_3 .

Fuse the mixed oxides with a few grams of potassium pyrosulfate. Dissolve the fusion in about 20 ml of hot 1:1 HCl (Note 4), and reduce the iron by dropwise addition of stannous chloride solution until the yellow color disappears, adding two drops in excess. Cool the solution to room temperature; add rapidly, in one portion, 10 ml of saturated mercuric chloride solution; and allow the mixture to stand for 2 min.

Transfer the solution to a 600-ml beaker containing 400 ml of water and 25 ml of Reinhardt's solution (4), and titrate immediately with standard 0.1*N* potassium permanganate. Record the volume and normality of the permanganate solution used, and calculate the milligrams of Fe_2O_3 in the mixed oxides and the percentage of Fe_2O_3 in the sample. Subtract the milligrams of Fe_2O_3 from the milligrams of mixed oxides to determine the Al_2O_3 that was dissolved in the acid treatment.

NOTE 1. If a large amount of iron or aluminum (200 mg or more) is present, the solution may begin to bump when most of the metal has been precipitated.

If this happens, remove the solution from the hot plate and filter it (Whatman No. 41). Wash the precipitate with 1 per cent succinic acid solution neutralized to methyl red with ammonium hydroxide, returning the filtrate and washings to the hotplate and boiling for the balance of the 90 min. Water should be added from time to time during the boiling period so that the final volume is about 150 ml.

NOTE 2. As the amount of aluminum and iron to be recovered is small and their separation from copper, calcium, and magnesium is already complete, the ammonia precipitation is used.

NOTE 3. This ignition should not be made in platinum, for, when the mixed oxides are later fused with potassium pyrosulfate, a milligram or so of platinum is dissolved. When the iron is subsequently reduced with stannous chloride, the platinum imparts a strong yellow color to the solution, which interferes with the visual endpoint of the reduction. Furthermore, if lead is present in the original sample, it may appear and damage a platinum crucible.

NOTE 4. Occasionally a small amount of Fe_2O_3 will remain undissolved when the melt is taken up in hydrochloric acid. If the amount is not too large, it will be dissolved by the reducing action of the stannous chloride. If particles of Fe_2O_3 remain after the disappearance of the yellow color, add two drops of stannous chloride in excess and boil the solution. If the yellow color reappears, reduce it, add two drops in excess, and repeat the boiling, if necessary. Two milligrams of ignited Fe_2O_3 will require about 30 min to dissolve by the foregoing treatment; therefore, every precaution should be taken to obtain a clear flux during the fusion.

B7.2. Copper. Heat the filtrate from the basic succinate precipitation to about 60°C, and bubble a slow stream of hydrogen sulfide through the solution for about 5 min to precipitate

copper sulfide (Note 1). Allow the precipitate to coagulate on a steam plate for a few minutes, and filter through Whatman No. 41H filter paper, washing the precipitate with a saturated solution of hydrogen sulfide. To the filtrate add 5 ml of hydrochloric acid, and boil to remove hydrogen sulfide. Cool, dilute to 250 ml in a volumetric flask, and reserve the solution for treatment in Procedures B7.3 and B7.4.

Transfer the paper and copper sulfide precipitate obtained above to a 250-ml beaker, add 10 ml of sulfuric acid, and heat to fuming. When the paper is well charred, oxidize the organic matter by dropwise addition of nitric acid, finally evaporating to dryness.

Cool the beaker and dissolve the copper sulfate in about 100 ml of water to which has been added 10 ml of acetic acid. Add 5 g of potassium iodide, and titrate with 0.1*N* sodium thiosulfate to the starch endpoint, adding 2 g of potassium thiocyanate just before the endpoint in the usual way (Note 2).

NOTE 1. If zinc is present, it will separate with the copper as sulfide but will not interfere with the copper determination. If it is desired to determine zinc as well, the solution should be acidified with about 5 ml of hydrochloric acid before passing the hydrogen sulfide through it. Copper alone will precipitate, and the zinc can be precipitated, after filtering off the copper sulfide, by neutralizing the filtrate again with ammonium hydroxide.

NOTE 2. Sodium thiosulfate is customarily standardized against metallic copper for this purpose.

B7.3. Magnesium. Transfer a 50-ml aliquot of the combined filtrate and

washings from the copper sulfide precipitation to a 400-ml beaker, dilute to 200 ml, and heat to about 60°C. Add a few drops of phenolphthalein, and neutralize with ammonium hydroxide until a permanent pink color is obtained. Maintaining the solution at 60°C, precipitate magnesium hydroxyquinolate (Note 1) by dropwise addition of 10 ml of a 5 per cent solution of 8-hydroxyquinoline (oxine) in 2*N* acetic acid. Add ammonium hydroxide until the phenolphthalein color is again visible (Note 2), and set the solution aside for at least 2 hr. At the expiration of the standing period, filter the solution through Whatman No. 7 filter paper and wash thoroughly with hot water.

Dissolve the precipitate in 20 ml of warm acetic acid, dilute to 200 ml, add 1 ml of oxine solution, and reprecipitate as above. After the 2-hr standing period, filter the solution through a coarse sintered-glass crucible and wash with hot water. Washing may be considered sufficient when no odor of oxine is detected in the crucible. Discard the filtrate and washings of both precipitations.

Dry the crucible in an oven at either 100°–105°C or 130°–140°C (Note 3) for at least 1 hr, cool, and weigh. Using the appropriate gravimetric factor, compute the percentage of MgO in the deposit.

NOTE 1. Magnesium hydroxyquinolate separates as a yellowish-green precipitate.

NOTE 2. A 10-ml quantity of oxine solution will make the mixture acidic and may redissolve the precipitate initially formed. It is therefore necessary to neutralize again with ammonium hydroxide. It will be noted that the precipitate adsorbs phenolphthalein strongly, and more indicator may be needed. It

is washed out later by the hot water. An attempt should be made at this point to judge whether too much precipitate has been formed. If it covers the entire bottom of the beaker to a depth of more than $\frac{1}{16}$ in., it will probably exceed the 0.15-g limit.

NOTE 3. The magnesium derivative may be weighed in either of two forms. It precipitates as the dihydrate, $Mg(C_9H_8ON)_2 \cdot 2H_2O$, and is weighed as such after drying at 100°–105°C. The gravimetric factor for MgO is 0.1157. If desired, the precipitate may be dried at 130°–140°C and weighed as the anhydrous compound, $Mg(C_9H_8ON)_2$. The MgO factor for this form is 0.1291. Of the two forms, the dihydrate is probably the better for weighing, unless a large excess of precipitant has been used. At the higher temperature range much of any coprecipitated oxine is volatilized. If the weight of the precipitate is greater than 150 mg, a smaller aliquot must be used. If the precipitate, after drying, has a shiny appearance, coprecipitation is indicated.

B7.4. *Calcium.* Transfer a 100-ml aliquot of the solution obtained in Procedure B7.2 to a 250-ml beaker, acidify to methyl red with hydrochloric acid, and add 2 ml in excess. To the solution add 25 ml of saturated ammonium oxalate solution, heat to 60°C, and precipitate $CaC_2O_4 \cdot H_2O$ by dropwise addition of ammonium hydroxide, continuing until the indicator just turns yellow. Remove the beaker from the heat, and allow it to cool to room temperature. Filter the solution through Whatman No. 40 paper, and wash the beaker and precipitate with water. Discard the filtrate and washings, place the original beaker under the funnel, fill the paper half full of water, punch a hole in the paper with a small stirring rod, and wash the precipitate into the beaker. Add 100 ml of water and

25 ml of 1:1 sulfuric acid, heat the solution to about 80°C, and titrate slowly with 0.1*N* KMnO₄ to a stable pink endpoint. Push the paper into the solution, stir to disintegrate it, and complete the titration. Record the titration and normality of the permanganate, and calculate the percentage of CaO in the deposit.

B7.5. Aluminum and magnesium unattacked by acids. Dilute the filtrate from Procedure B3 to about 150 ml (Note 1), heat the solution to boiling, and neutralize it to methyl red by dropwise addition of ammonium hydroxide. Allow the mixture to digest for a few minutes, and filter through Whatman No. 41 filter paper, washing the precipitate with 1 per cent ammonium chloride solution. Ignite the precipitate and filter paper as described in Procedure B7.1, recording the weight as Al₂O₃ (Note 2).

Neutralize the filtrate to phenolphthalein with ammonium hydroxide, and precipitate magnesium as the hydroxyquinolate, as previously described in Procedure B7.3.

NOTE 1. Before any work is done on this solution, a summation of the silica losses and residue weights should be made. Often this solution contains no cations from the deposit and need not be worked at all. The following is an example:

| | Weight mg |
|--|--------------|
| First residue (B1)..... | 260.2 |
| SiO ₂ loss (B2)..... | - 202.6 |
| Second residue | 57.6 |
| SiO ₂ loss (B3)..... | - 26.0 |
| Material in solution from carbonate fusion..... | 31.6 |

From the above it is seen that 31.6 mg of aluminum or magnesium (or both) should be found in the solution to be examined in this procedure. Discrepancies of 1-3 mg may be disregarded. Larger discrepancies indicate that MgSO₄ was present in this residue. (See the example in Part D, page 918.)

NOTE 2. In rare instances, a significant amount of iron oxide may occur. It is easily recognized by the color of the residue. If it appears advisable, the mixed oxides may be treated as described in Procedure B7.1.

Part C—Determination of Other Components

An attempt has been made to provide in Part B a system for determining the chemical composition of any deposit containing the components discussed. In addition to these, carbonate and sodium are commonly found in internal deposits. Carbonate is usually determined by an evolution method, the details of which are well known. Its presence will have been indicated by effervescence when hydrochloric acid was added to the sample in Procedure B1. A portion of the dried, extracted residue from Procedure A is employed for the determination.

Clarke (6) has described a useful apparatus and procedure.

Determination of Sodium

Sodium is always present in small amounts but is not usually a major component. If the total analysis amounts to less than 90 per cent of the sample, it should be examined for sodium. A small sample is taken and treated by Procedure B1; interfering phosphate is removed with zinc carbonate; and sodium is precipitated and weighed as sodium zinc uranyl

acetate. The zinc carbonate must contain less than 0.002 per cent sodium. It may be necessary to remove the zinc carbonate with water, utilizing a Soxhlet extractor for several hours, to reduce the sodium content to this value. A blank must be carried through the operations. The zinc uranyl acetate reagent and the alcohol wash solution are prepared as described by Hillebrand and colleagues (4).

Procedure C

Weigh a 100-mg sample of the residue from Procedure A and treat it with acids (Note 1) as described in Procedure B1, but do not add hydroxylamine hydrochloride. Cool, add 50 ml of distilled water, heat to boiling, and boil gently for 5-10 min. Remove from the heat, add a few drops of bromthymol blue indicator, and then add ammonium hydroxide dropwise until the indicator just turns blue. Carefully neutralize with dilute hydrochloric acid until the indicator just turns yellow. Sift 5 g of zinc carbonate into the solution and let stand 4-6 hr.

Filter through Whatman No. 42 paper, washing 5-6 times with 1 per cent ammonium nitrate solution and receiving the filtrate and washings in a small beaker. Evaporate the solution to approximately 2 ml, discarding the filter paper and precipitate.

Add 25 ml of zinc uranyl acetate reagent to the above solution and stir well. Allow the solution to stand 30 min, and filter through a sintered-glass filter crucible. Wash the precipitate with four 10-ml portions of reagent and four 10-ml portions of alcohol wash solution; rinse three or four times with ether. Dry by suction, wipe the outside of the crucible, let stand 30 min, and weigh. Calculate the percentage of sodium in the original sample, deducting a blank from the weight of sodium zinc uranyl acetate found.

NOTE 1. Some types of scale containing sodium are not attacked by acids—for example, analcite, $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. In such instances, sodium is best determined by the J. L. Smith method (4). For the majority of deposits, however, the procedure given yields satisfactory results.

Part D—Reporting of Results

After the procedures in Parts B and C have been completed, the data obtained must be organized into a report. During the analysis a running account of the partition of the sample is kept; this tabulation is of value in interpreting the results. The acid-soluble and -insoluble components are separated in both the running account and the final report.

This section gives an example of a deposit analysis and its interpretation. To simplify the discussion, the weights of the various residues and components

obtained in each procedure are recorded in Table 1. It will be noted that the total weight of acid-insoluble material is equal to the weight of the first residue (Procedure B2), while the total weight of the acid-soluble material is the difference between the weight of the sample and that of the first residue. The final form of the report is shown in Table 2.

In this example 1,097 mg of sample was taken. The weight of the first residue is 494 mg. Subtracting 494 from 1,097 leaves 603 mg, which is

the weight of material dissolved by the acid treatment in Procedure B1. In Procedures B5-B7.4, 324 mg is accounted for, leaving 279 mg undetermined. It is apparent that other acid-soluble components must be present or else a gross error has been made. Sodium is next determined on a new

TABLE 1
Deposit Analysis
(400-psi Boiler Superheater)

| Procedure | Component | Weight Found—mg | |
|-----------|--------------------------------|-----------------|--------------|
| | | Acid Insoluble | Acid Soluble |
| B1 | Sample | 1,097 | |
| B2 | First residue | 494 | |
| | SiO ₂ | 427 + 30* | |
| B3 | Second residue | 67 | |
| | Third residue | none | |
| B5 | P ₂ O ₅ | 75 | |
| B6 | SO ₃ | 19 | |
| B7.1 | Fe ₂ O ₃ | 35 | |
| B7.2 | MgO | 15 | |
| | Al ₂ O ₃ | 89 | |
| B7.3 | CaO | 91 | |
| B7.4 | Fe ₂ O ₃ | 21 | |
| | Al ₂ O ₃ | none | |
| | MgO | 15 | |
| C | Na | 160† | |
| | CO ₂ | 26† | |
| | Cl | 7† | |
| | Unaccounted for | 1 | 86 |
| | | | 603 |

* Correction due to the presence of MgSO₄ in the second residue.

† The weight that would have been present in a 1,097-mg sample. Separate samples were used for these determinations.

sample. On the basis of a 1,097-mg sample, it is found that 160 mg of sodium is present, leaving 119 mg to be accounted for. A chloride determination gives an additional 7 mg, and carbonate 26 mg. Finally 86 mg remains unaccounted for, representing about 7.8 per cent of the entire deposit.

The presence of so much iron oxide in the second residue suggests that it was probably deposited as silicate. As the deposit contains only 5 per cent total iron as Fe₂O₃, it would have dissolved completely in Procedure B1 if it had actually been present as oxide. The visual appearance of the first residue confirms this conclusion. The fact that no aluminum oxide was found in the second residue indicates that the scale is not of a very resistant variety. The presence of so many different

TABLE 2
Final Report of Analysis

| Component | Amount—per cent | | |
|--------------------------------|-----------------|----------------|-------|
| | Acid Soluble | Acid Insoluble | Total |
| SiO ₂ | | 41.7 | 41.7 |
| P ₂ O ₅ | 6.9 | | 6.9 |
| SO ₃ | 1.7 | | 1.7 |
| Fe ₂ O ₃ | 3.2 | 1.9 | 5.1 |
| Al ₂ O ₃ | 8.2 | | 8.2 |
| CaO | 8.3 | | 8.3 |
| MgO | 1.3 | 1.4 | 2.7 |
| Na | 14.6 | | 14.6 |
| CO ₂ | 2.4 | | 2.4 |
| Cl | 0.6 | | 0.6 |
| | 47.3 | 45.0 | 92.3 |

components in a superheater tube shows that mechanical carryover has occurred. This might have been caused by "priming" (foaming of the boiler water) or by a faulty steam washer. In this instance, the steam washer was found to have a structural crack, which was welded closed before putting the boiler back in service.

As has been mentioned before, if magnesium is found in the second residue, the silica loss must be corrected, because the second residue will contain magnesium sulfate instead of

oxide. In this example, the actual weight of the second residue was 66.7 mg, of which 20.8 mg was Fe_2O_3 and 15.3 mg MgO . The MgO is actually present as MgSO_4 after the hydrofluoric acid treatment in Procedure B2, causing the weight of the second residue to be too large. A correction is made by converting the weight of MgO found to the equivalent weight of MgSO_4 :

$$15.3 \times \frac{120.4}{40.3} = 45.7 \text{ mg } \text{MgSO}_4$$

$45.7 + 20.8 = 66.5$ mg, effectively accounting for all of the second residue. As this residue is $45.7 - 15.3 = 30.4$ mg too heavy, this weight is added to the silica weight loss obtained in Procedure B2.

This deposit presents more of an analytical problem than most because, of the eleven components determined, only two are present in amounts greater than 10 per cent. Much more work was done on this sample than would ordinarily be justified. The presence of so much aluminum caused considerable concern, and, in addition to two complete chemical analyses, a spectrographic analysis and an X-ray diffraction examination were made. The latter showed the presence of the sodalite structure, $3\text{Na}_2\text{O} \cdot 3\text{Al}_2\text{O}_5 \cdot 6\text{SiO}_2 \cdot 2\text{NaCl}$ in the sample. As this mineral is readily decomposed by hydrochloric acid, while ignited aluminum oxide is not, it is likely that all of the aluminum was in this form.

Based on the aluminum content, about 25 per cent of the scale was sodalite. Because the scale was formed by flash evaporation rather than by depositing from solution, it was not difficult to remove from the tubes.

It has been implied that at least a 90 per cent analysis should be obtained. With all deposits examined by this system, such a standard has been met. It should be pointed out, however, that the principal reason for the examination is to find out what type of deposition has occurred—hard scale, soft scale, corrosion, phosphate mud, or other—and how to remove it. An analysis as extensive as that in the example given is usually not required.

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Census of Fluoridation in the United States and Canada, 1953

Committee Report

A report of Committee E5.10—Fluoridation Materials and Methods, presented on May 25, 1954, at the Annual Conference, Seattle, Wash., by W. L. Harris (Chairman), Supt., Dept. of Water & Light, Grand Rapids, Mich. Other members of the committee were: C. R. Cox, R. L. Derby, H. A. Faber, M. E. Flentje, F. J. Maier, H. C. Medbery, O. J. Muegge, R. W. Ockershausen, R. S. Phillips, L. A. Smith, F. S. Taylor, D. B. Williams, and J. C. Zufelt.

WATER fluoridation in North America continued to show a large and orderly growth in 1953. As of Dec. 31, 1953, there were more than 840 communities in the United States using fluoridated water supplies to supply almost 16,000,000 people. Approximately 192,000 persons in twelve Canadian communities were also receiving fluoridated water. Detailed information on installations in the United States and Canada from 1945 through Dec. 31, 1953 (except for communities that started but later discontinued fluoride application), is given in Table 1 and summarized in Table 2 (page 935).

Fluoridation Chemicals

The principal chemicals used as the source of fluoride ion continue to be sodium fluoride and silicofluoride (Table 3). In the United States, both compounds are produced in the East, Middle West, and West, and are in good supply. Sodium silicofluoride is not manufactured in Canada but its supply of sodium fluoride is virtually unlimited. At present only 6-8 weeks' operation of a byproduct division of an aluminum plant meets the annual

sodium fluoride requirements for all purposes in Canada.

The supply of fluosilicic acid is considered adequate, but the distribution of this material is usually limited to the locality in which it is produced. Ammonium silicofluoride usage is relatively minor and the supply is adequate. The varied availability and quality of imported materials have discouraged their use, so that they are not a significant factor in the general supply picture.

Sodium fluoride is being quoted in the United States at \$12.50 per 100 lb in carload and truckload lots (fob factory); smaller quantities are \$12.90 per 100 lb. In Canada, the price for double-ground sodium fluoride at the warehouse distributing point is \$13.00 per 100 lb; the single-ground material is \$11.50 per 100 lb. Sodium silicofluoride is quoted in the United States at \$7.00 per 100 lb in carload and truckload lots and at \$7.40 for smaller amounts (prices fob factory). The price in Canada is extremely variable. In March 1954 it was \$6.00 per 100 lb. Fluosilicic acid (30 per cent) is selling for 7-9 cents per pound in drums (less than carload or truckload lots, fob fac-

TABLE 1—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|----------------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Alabama | | | | | | | |
| Sheffield | 10,767 | | D | | 0.1— | 0.75—1.0 | 12/52 |
| Tuscaloosa (+2) | 52,734 | | D | | 0.2— | 0.75—1.0 | 7/51 |
| Arizona | | | | | | | |
| None | | | | | | | |
| Arkansas | | | | | | | |
| Arkadelphia | 6,819 | | D | | 0.1 | 1.0 | 6/53 |
| Camden | 11,372 | | D | | 0.1 | 1.0 | 7/53 |
| Jonesboro | 17,692 | | D | | 0.0 | 1.0 | 10/51 |
| Nettleton | | | | | | | |
| Lewisville | 1,237 | S | | | 0.2 | 1.1 | 1/53 |
| Little Rock (+3) | 147,210 | | D | | trace | 1.0 | 3/51 |
| Searcy (+2) | 6,002 | | | | | | 12/53 |
| Springdale | 7,000 | | D | | 0.1 | 1.0 | 11/52 |
| Walnut Ridge | 3,106 | S | | | 0.0 | 1.0 | 1/52 |
| California | | | | | | | |
| Antioch | 11,051 | | D | | 0.0 | 1.0 | 8/52 |
| Healdsburg | 3,258 | | D | | 0.0 | 1.0 | 1/53 |
| Morgan Hill | 1,627 | S | | | 0.1 | 1.0 | 3/52 |
| Rio Vista | 1,831 | | D | | 0.1 | 1.0 | 9/51 |
| San Diego | 434,924 | | D | | 0.5— | 1.0 | 11/52 |
| San Francisco | 827,400 | | D | | 0.1 | 1.0 | 8/52 |
| Colorado | | | | | | | |
| Craig | 3,080 | | D | | trace | 1.0 | 4/53 |
| Grand Junction | 14,435 | | D | | 0.2— | 1.0 | 7/51 |
| Johnstown | 897 | St | | | 0.3 | 1.0 | 7/52 |
| Lafayette | 2,090 | St | | | 0.3 | 1.0 | 8/52 |
| Louisville | 1,978 | | | | | | 4/53 |
| Montrose | 4,964 | S | | | 0.2 | 1.0 | 4/53 |
| Palisade | 861 | | | | 0.2 | 1.0 | 12/52 |
| Connecticut | | | | | | | |
| Cromwell Fire Dist. | 2,500 | St | | | 0.0 | 1.0 | 6/51 |
| Mansfield State Tr. School | 1,700 | S | | | 0.0 | 1.0 | 11/50 |
| Mystic (P) | 10,539 | | D | | 0.0 | 1.0 | 4/53 |
| Stonington Borough | | | | | | | |
| Stonington Fire Dist. | | | | | | | |
| West Mystic | | | | | | | |
| New Britain | 80,913 | D | | | 0.0 | 1.0 | 12/50 |
| Berlin | | | | | | | |
| Southbury State Tr. School | 1,800 | S | | | 0.0 | 1.0 | 4/45 |
| Delaware | | | | | | | |
| Newark | 6,731 | S | | | | 0.4—0.9 | 11/50 |

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; W.D.—water district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder. A number in parentheses following the name of a city indicates the number of other communities served by it.

TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|----------------------------------|-------------------|---------------|----------------------------------|---------------------------------|------------------|---------------------------------|-------------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| District of Columbia (+4) | 1,005,000 | | D | | 0.3— | 1.0 | 6/52 |
| Florida | | | | | | | |
| Clewiston (P) | 2,485 | | D | | 0.3— | 0.6—1.1 | 10/51 |
| Gainesville | 26,577 | D | | | 0.3— | 0.6—1.1 | 10/49 |
| Miami (+7) | 354,117 | | D | | 0.2 | 0.6—1.1 | 4/52 |
| Georgia | | | | | | | |
| Albany | 31,155 | | | | | | 11/53 |
| Athens | 28,102 | D | | | 0.0 | 0.7—1.0 | 5/51 |
| DeKalb County (+13) | 134,931 | | D | | 0.0 | 0.7—1.0 | 4/51 |
| Gainesville | 11,936 | S | | | 0.0 | 0.7—1.0 | 6/52 |
| Monroe | 4,542 | D | | | 0.0 | 0.7—1.0 | 8/52 |
| Rome | 29,615 | D | | | 0.0 | 0.7—1.0 | 6/52 |
| Other† | 8,585 | | | | | | |
| Idaho | | | | | | | |
| Bonners Ferry | 1,776 | | D | | 0.0 | 1.0 | 3/52 |
| Coeur d'Alene (P) | 12,198 | | D | | 0.0 | 1.0 | 1/52 |
| Lewiston | 12,985 | D | | | 0.0 | 1.0 | 6/47 |
| Lewiston Orchards Dist. (P) | 4,494 | D | | | 0.0 | 1.0 | 3/52 |
| McCall | 1,180 | | D | | 0.0 | 1.0 | 11/52 |
| Montpelier | 2,682 | | D | | 0.0 | 1.0 | 8/53 |
| Preston | 4,045 | | D | | 0.0 | 1.0 | 1/52 |
| Salmon | 2,648 | | D | | 0.0 | 1.0 | 11/52 |
| Sandpoint (+2) | 4,714 | | D | | 0.0 | 1.0 | 3/52 |
| Illinois | | | | | | | |
| Assumption | 1,466 | | S | | 0.3 | 1.0 | 9/51 |
| Carbondale | 11,567 | | D | | 0.1 | 1.0 | 7/52 |
| DeSoto | | | | | | | |
| Carlyle | 3,714 | | D | | 0.1 | 1.0 | 6/52 |
| Beckemeyer | | | | | | | |
| Casey | 2,734 | S | | | 0.4 | 1.0 | 8/52 |
| Chester | 5,389 | | D | | 0.3 | 1.0 | 12/51 |
| Dixon State School | 5,000 | | | | | | 12/53 |
| Evanston | 81,057 | D | | | 0.1 | 1.0 | 2/47 |
| Skokie | | | | | | | |
| Kenilworth | 2,789 | | D | | 0.1 | 1.0 | 1/53 |
| Lansing† | 8,682 | | D | | 0.1 | 1.0 | 3/53 |
| Lawrenceville (P) (+2) | 9,856 | S | | | 0.1 | 1.0 | 9/53 |
| Leroy | 1,820 | S | | | 0.3 | 1.0 | 1/53 |
| Normal | 9,772 | | D | | 0.3 | 1.0 | 12/53 |
| Orion | 829 | D | | | 0.4 | 1.0 | 9/52 |
| Park Forest (P) | 8,138 | D | | | 0.4 | 1.0 | 12/52 |
| Pleasant Hill | 856 | S | | | 0.3 | 1.0 | 6/53 |

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† Including Fort Oglethorpe, Rossville, and parts of Catoosa and Walker counties, served by Chattanooga, Tenn.

‡ Served by Hammond, Ind.

TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|------------------------------------|-------------------|---------------|----------------------------------|---------------------------------|------------------|---------------------------------|-------------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Illinois (contd.) | | | | | | | |
| Soldiers & Sailors Children's Home | 286 | S | | | 0.3 | 1.0 | 9/52 |
| Waukegan | 38,946 | D | | | 0.1 | 1.0 | 3/52 |
| Winnetka | 13,950 | D | | | 0.1 | 1.0 | 12/52 |
| Northfield | | | | | | | |
| Indiana | | | | | | | |
| Batesville | 3,785 | S | | | 0.1- | 1.0 | 3/52 |
| Oldenburg | | | | | | | |
| Bedford | 13,687 | D | | | 0.2- | 1.0 | 1/52 |
| Oolitic | | | | | | | |
| Bloomfield (P) | 2,086 | D | | | 0.0 | 1.0 | 9/52 |
| Columbus | 18,370 | D | | | 0.0 | 1.0 | 1/52 |
| Culver | 1,563 | S | | | 0.1 | 1.0 | 1/53 |
| Elkhart | 35,646 | D | | | 0.0 | 1.0 | 5/53 |
| Fort Wayne | 140,000 | D | | | 0.3 | 1.0 | 7/51 |
| Greensburg | 6,619 | D | | | 0.3 | 1.0 | 4/53 |
| Hammond (+4) | 107,072 | D | | | 0.1 | 1.0 | 3/53 |
| Huntingburg | 4,056 | D | | | 0.2- | 1.0 | 8/51 |
| Indianapolis (P) (+8) | 490,265 | D | | | 0.2 | 1.0 | 8/51 |
| Kokomo (P) | 38,672 | D | | | 0.4 | 1.0 | 7/52 |
| Lafayette | 35,646 | D | | | 0.1 | 1.0 | 6/53 |
| Lyons | 695 | S | | | 0.2- | 1.0 | 4/52 |
| Marion | 30,059 | D | | | | 1.0 | 9/52 |
| Martinsville | 5,991 | S | | | 0.0 | 1.0 | 5/53 |
| Michigan City | 28,379 | D | | | 0.2- | 1.0 | 3/52 |
| New Carlisle | 983 | S | | | 0.0 | 1.0 | |
| Tell City | 5,735 | D | | | 0.1 | 1.0 | 5/52 |
| Valparaiso | 14,028 | D | | | 0.0 | 1.0 | 10/52 |
| Flint Lake Wtr. Co. | | | | | | | |
| Walkerton | 2,102 | S | | | 0.0 | 1.0 | 2/53 |
| Zionsville | 1,536 | S | | | 0.6- | 1.0 | 11/51 |
| Iowa | | | | | | | |
| Audubon | 2,808 | S | | | 0.3 | 1.2 | 5/53 |
| Cedar Rapids | 72,149 | D | | | 0.2 | 1.2 | 5/52 |
| Clarinda | 5,086 | D | | | 0.3 | 1.2 | 11/52 |
| Creston | 8,317 | D | | | 0.3 | 1.2 | 4/53 |
| Davenport (P) | 78,750 | D | | | 0.15 | 1.2 | 7/52 |
| Bettendorf | | | | | | | |
| Dubuque | 49,671 | D | | | trace | 1.2 | 10/51 |
| Eagle Grove | 4,176 | S | | | 0.3 | 1.2 | 1/53 |
| Fairfield | 7,042 | D | | | 0.45 | 1.2 | 12/52 |
| Harlan | 3,915 | D | | | 0.3 | 1.2 | 2/53 |
| Hartley | 1,614 | S | | | 0.6 | 1.2 | 8/52 |
| Indianola | 5,146 | D | | | 0.1 | 1.2 | 12/52 |
| Iowa City (+2) | 27,475 | S | | | 0.2 | 1.2 | 7/53 |

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TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|----------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Iowa (contd.) | | | | | | | |
| Manchester | 3,969 | S | | | 0.2 | 1.2 | 12/52 |
| Perry | 5,977 | | | | | | 11/53 |
| Waukon | 3,158 | S | | | 0.15 | 1.2 | 10/51 |
| Kansas | | | | | | | |
| Garnett | 2,693 | | | | S | 0.2 | 1.0 |
| Hays | 8,600 | | D | | | 0.2 | 1.0 |
| Horton | 2,900 | | | | S | 0.3 | 1.0 |
| Iola (+2) | 7,920 | | | | S | 0.2 | 1.0 |
| Junction City | 14,000 | | D | | | 0.3 | 1.0 |
| Lawrence | 18,638 | | D | | | 0.3 | 1.0 |
| Minneapolis | 1,769 | | | | S | 0.3 | 1.0 |
| Ottawa | 10,000 | S | | | | 0.3 | 1.0 |
| Paola | 4,152 | | D | | | 0.2 | 1.0 |
| Parsons | 14,706 | | | | | | 3/53 |
| Seneca | 1,945 | | | | S | 0.2 | 1.0 |
| Kentucky | | | | | | | |
| Ashland | 39,800 | | D | | | 0.0 | 1.2 |
| Berksville | 622 | | | | | | 11/52 |
| Central City | 4,110 | | D | | | 0.0 | 1.2 |
| Cynthiana | 4,847 | | D | | | 0.0 | 1.2 |
| Elizabethtown | 5,807 | | D | | | 0.0 | 1.2 |
| Franklin | 4,343 | | S | | | 0.0 | 1.2 |
| Glasgow | 7,025 | | D | | | 0.0 | 1.2 |
| Greensburg | 1,032 | | | | S | 0.0 | 1.2 |
| Hopkinsville | 12,526 | D | | | | 0.0 | 1.2 |
| Lancaster | 2,500 | D | | | | 0.0 | 1.2 |
| Louisville (+19) | 403,279 | | D | | | 0.0 | 1.2 |
| Martin | 1,170 | S | | | | 0.0 | 1.2 |
| Mayfield | 8,990 | D | | | | 0.0 | 1.2 |
| Maysville | 8,632 | D | | | | 0.0 | 1.2 |
| Morehead | 3,082 | | | | | | 4/52 |
| Owensboro | 30,245 | | | | | | 9/52 |
| Paintsville | 4,309 | | | | | | 4/51 |
| Versailles | 2,760 | D | | | | 0.0 | 1.2 |
| Louisiana | | | | | | | |
| St. Martinville | 4,604 | D | | | | 0.17 | 1.0 |
| Maine | | | | | | | |
| Norway (P) | 3,100 | | D | | | trace | 1.0 |
| Maryland | | | | | | | |
| Baltimore Met. Dist. | 1,180,000 | | | | S | 0.2— | 1.0 |
| Bel Air (P) | 2,538 | S | | | | 0.1 | 11/52 |
| | | | | | | | 11/52 |

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TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|--------------------------|-------------------|---------------|----------------------------------|---------------------------------|------------------|---------------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Maryland (contd.) | | | | | | | |
| Hagerstown (+7) | 43,119 | | D | | 0.4— | 1.0 | 12/51 |
| Washington Suburban S.D. | 310,000 | | D | | | 1.0 | 12/51 |
| Massachusetts | | | | | | | |
| Athol | 11,554 | | D | | 0.1 | 1.0 | 1/52 |
| Belchertown State School | 1,536 | S | | | 0.1 | 1.0 | 11/46 |
| Concord† (P) | 300 | S | | | 0.5 | 1.0 | 8/52 |
| Danvers | 18,636 | | D | | 0.08 | 1.1 | 5/51 |
| Middleton | | | | | | | |
| Hingham (P) | 14,025 | D, S | D, S | | 0.12— | 1.0 | 5/53 |
| Hull | | | | | | | |
| Hudson | 8,211 | D, S | D, S | | 0.1 | 1.0 | 2/53 |
| Medway | 3,744 | D | | | 0.11 | 1.0 | 2/53 |
| North Andover | 8,429 | S, St | | | 0.14 | 1.0 | 8/53 |
| Salem | 70,764 | | D | | 0.14 | 1.0 | 12/52 |
| Beverly | | | | | | | |
| Seekonk | 6,104 | | S | | 0.06 | 1.0 | 1/52 |
| Sharon | 4,847 | | D | | 0.1— | 1.0 | 2/53 |
| Shrewsbury | 10,594 | St | | | 0.12 | 1.0 | 2/53 |
| Templeton | 4,757 | | D | | 0.08 | 1.0 | 6/51 |
| Wrentham State School | 2,234 | S | | | 0.12— | 1.0 | 11/46 |
| Michigan | | | | | | | |
| Algoma | 3,039 | | D | | 0.0 | 1.0 | 9/49 |
| Pearl Harbor | | | | | | | |
| Ann Arbor | 48,251 | | D | | 0.25 | 1.0 | 12/51 |
| Battle Creek | 48,666 | | D | | 0.0 | 1.0 | 4/51 |
| Bay City | 55,690 | | D | | 0.0 | 1.0 | 1/52 |
| Essexville | | | | | | | |
| Benton Harbor | 18,769 | D | | | 0.45 | 1.0 | 9/51 |
| Buchanan | 5,224 | S | | | 0.08 | 1.0 | 10/52 |
| Charlevoix | 2,695 | | | | S | 0.0 | 1.0 |
| Grand Haven | 9,536 | | | | S | 0.15 | 1.0 |
| Grand Rapids (+3) | 176,515 | D | | | | 0.0 | 1.0 |
| Grosse Pointe Farms | 15,693 | | D | | | 0.0 | 1.0 |
| Grosse Pointe Village | | | | | | | |
| Hastings | 6,096 | | D | | 0.0 | 1.0 | 1/51 |
| Highland Park | 46,393 | | D | | 0.0 | 1.0 | 9/52 |
| Ishpeming | 8,962 | | | | | 0.0 | 1.0 |
| Jackson | 51,088 | | D | | | 0.5 | 1.0 |
| Kalamazoo | 57,704 | D | | | | 0.0 | 1.0 |
| Lake Odessa | 1,596 | | | | S | 0.0 | 1.0 |
| Ludington | 12,006 | S | | | | 0.1 | 1.0 |
| Epworth Heights | | | | | | | |
| Mancelona | 1,000 | | | | | 1.0 | 9/53 |
| Marquette | 17,202 | | D | | | 0.7 | 1.0 |
| Marysville | 2,534 | | D | | | 0.15 | 1.0 |
| | | | | | | | 4/52 |

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† Part of city only.

TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

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|------------------------------|-------------------|---------------|----------------------------------|---------------------------------|------------------|---------------------------------|-------------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Michigan (contd.) | | | | | | | |
| Midland | 14,285 | | D | | 0.15 | 1.0 | 1/46 |
| Monroe | 21,467 | | D | | 0.1 | 1.0 | 12/51 |
| Mt. Clemens | 19,027 | | D | | 0.0 | 1.0 | 3/51 |
| Harrison Twp. | | | | | | | |
| Muskegon | 50,853 | D | | | 0.0 | 1.0 | 7/51 |
| North Muskegon | | | | | | | |
| Muskegon Heights | 18,829 | D | | | 0.0 | 1.0 | 1/52 |
| Negaunee | 6,472 | | D | | 0.0 | 1.0 | 11/51 |
| Saginaw | 92,918 | | D | | 0.0 | 1.0 | 5/51 |
| St. Joseph | 10,223 | | D | | 0.0 | 1.0 | /53 |
| South Haven | 5,629 | | D | | 0.0 | 1.0 | 2/52 |
| Stambaugh | 3,967 | | D | | 0.0 | 1.0 | 9/53 |
| Stambaugh Twp. | | | | | | | |
| Tecumseh | 4,020 | | | | 0.0 | 1.0 | 4/53 |
| Traverse City | 16,974 | | D | | 0.1 | 1.0 | 5/52 |
| Wyandotte | 36,846 | | D | | 0.0 | 1.0 | 1/51 |
| Minnesota | | | | | | | |
| Appleton | 2,256 | S | | | 0.0 | 1.2 | 8/52 |
| Arlington | 1,313 | S | | | 0.5 | 1.2 | 1/52 |
| Austin | 23,100 | | D | | 0.1 | 1.2 | 5/52 |
| Benson | 3,398 | | D | | 0.15 | 1.2 | 1/52 |
| Blue Earth | 38,211 | | | | | | 8/53 |
| Circle Pines | 350 | | | | | | 6/52 |
| Cloquet | 7,685 | | | | | | 2/53 |
| Ely | 5,474 | D | | | 0.09 | 1.2 | 1/52 |
| Fairmont | 8,193 | | D | | 0.4 | 1.2 | 2/51 |
| Faribault | 14,527 | | | | | | 8/53 |
| Fergus Falls | 12,917 | | D | | 0.05 | 1.2 | 5/51 |
| Granite Falls | 2,511 | | D | | 0.18 | 1.2 | 12/51 |
| Hallock | 1,552 | S | | | 0.3 | 1.2 | 12/51 |
| Hutchinson | 4,690 | | D | | 0.35 | 1.2 | 2/52 |
| International Falls (P) (+1) | 8,109 | | D | | 0.0 | 1.2 | 9/52 |
| Madison | 2,303 | | | | | | 1/53 |
| Mapleton | 1,083 | | D | | 0.08 | 1.2 | 9/52 |
| Montevideo | 5,459 | D | | | 0.26 | 1.2 | 10/51 |
| Mora | 2,018 | S | | | 0.1 | 1.2 | 5/52 |
| Morris | 3,811 | | D | | 0.0 | 1.2 | 11/52 |
| New York Mills | 977 | S | | | 0.16 | 1.2 | 8/52 |
| Okabena | 236 | | | | | | 12/52 |
| Perham | 1,926 | | | | | | 5/53 |
| Red Lake Falls | 1,733 | S | | | 0.0 | 1.2 | 4/51 |
| Rush City | 1,175 | S | | | 0.15 | 1.2 | 10/52 |
| St. Paul (+2) | 319,948 | | D | | 0.15 | 1.2 | 9/52 |
| Scanlon | 572 | | | | | | 6/52 |
| Staples | 2,782 | D | | | 0.78 | 1.2 | 4/52 |
| Thief River Falls | 6,926 | S | | | 0.1 | 1.2 | 9/51 |
| West Concord | 770 | S | | | 0.45 | 1.2 | 9/51 |
| Winnebago | 2,129 | S | | | 0.0 | 1.2 | 6/51 |

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| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|---------------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Mississippi | | | | | | | |
| Bay Springs | | | | | | | |
| Columbus | 1,299 | S | | | | | |
| Forest | 17,170 | | D | | 0.0 | 1.0 | 8/51 |
| Meridian | 2,875 | | D | | 0.2 | 1.0 | 2/52 |
| | 41,893 | | D | | 0.2 | 1.0 | 6/53 |
| Missouri | | | | | | | |
| None | | | | | | | |
| Montana | | | | | | | |
| Chinook | 2,250 | | D | | | 1.0 | 3/52 |
| Roundup | 2,862 | D | | | | 1.0 | 2/52 |
| Nebraska | | | | | | | |
| Beatrice | 11,788 | | D | | 0.15 | 1.2 | 4/51 |
| Fairbury | 6,395 | | D | | 0.1 | 1.2 | 3/52 |
| Nebraska City | 6,872 | | D | | 0.6— | 1.2 | 9/52 |
| Superior | 3,230 | | D | | 0.5 | 1.2 | 7/51 |
| Nevada | | | | | | | |
| None | | | | | | | |
| New Hampshire | | | | | | | |
| Concord | 27,954 | | D | | 0.1 | 1.0 | 5/52 |
| New Jersey | | | | | | | |
| Monmouth County (P) (+21) | 117,776 | | | | | | |
| Morristown (+3) | 25,000 | S | | | | 0.2—0.8 | 3/53 |
| Rahway | 21,287 | | D | | 0.2— | 1.0 | 2/50 |
| | | | | | | | 6/52 |
| New Mexico | | | | | | | |
| None | | | | | | | |
| New York | | | | | | | |
| Amsterdam | 32,269 | | | | 0.05 | | 4/53 |
| Carle Place† | 991 | | | | | 1.0 | 3/52 |
| Elmira | 70,000 | | D, St | | 0.05 | 1.0 | 2/53 |
| Fulton | 14,422 | | D | | 0.05 | 1.1 | 2/53 |
| Gloversville | 23,634 | | D, St | | 0.05 | 1.1 | 4/52 |
| Highland | 3,035 | S | | | 0.05 | 1.0 | 2/53 |
| Hoosick Falls | 4,297 | | D, St | | 0.05 | 1.0 | 9/52 |
| Larchmont | 6,330 | | D, St | | | | 2/53 |
| New Rochelle (+7) | 100,000 | D | | | 0.1 | 1.0 | 10/51 |
| Newburgh | 32,000 | D | | | 0.1 | 1.0 | 5/45 |
| Olean | 22,842 | | S | | 0.5 | 1.0—1.2 | 11/51 |
| Penn Yan | 5,481 | D | | | 0.1 | 1.1 | 2/53 |
| Poughkeepsie | 41,023 | | D | | 0.1 | 1.0 | 10/52 |

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; W.D.—water district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder. A number in parentheses following the name of a city indicates the number of other communities served by it.

† Uses ammonium silicofluoride with solution feeder.

TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|--------------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| New York (contd.) | | | | | | | |
| Rochester | 332,488 | | D | | 0.1 | 1.15 | 9/52 |
| Schenectady | 92,070 | | D, S | | 0.05 | | 2/53 |
| Westfield | 3,649 | | D | | 0.15 | 1.0 | 1/52 |
| North Carolina | | | | | | | |
| Albemarle | 11,751 | | | | 0.1 | | 1/54 |
| Charlotte | 135,835 | | D | | 0.0 | 0.6-1.1 | 4/49 |
| Morris Field | | | | | | | |
| Pineville | | | | | | | |
| Concord | 15,500 | | D | | 0.2 | | 9/50 |
| Dunn | 9,000 | | D | | 0.1 | | 4/53 |
| Fayetteville | 40,000 | | D | | 0.0 | | 10/52 |
| Greensboro | 81,000 | | D | | 0.0 | | 10/52 |
| Guilford College | | | | | | | |
| Hamilton Lakes | | | | | | | |
| Hickory | 14,691 | | D | | 0.0 | | 8/52 |
| High Point | 39,930 | | D | | 0.0 | | 7/52 |
| Lenoir | 7,836 | | D | | 0.0 | | 11/52 |
| Lexington | 14,249 | | D | | 0.1 | | 7/53 |
| Roanoke Rapids (P) | 8,123 | | D | | 0.1 | | 2/52 |
| Rockingham | 4,500 | | D | | 0.0 | | 12/52 |
| Rocky Mount | 27,644 | | D | | 0.2 | | 12/52 |
| Salisbury | 21,000 | | D | | 0.0 | | 7/52 |
| Southern Pines | 6,500 | | D | | 0.1 | | 11/52 |
| Sylva | 1,409 | | D | | 0.2 | | 5/52 |
| Winston-Salem | 86,816 | | D | | 0.1 | 0.8-1.2 | 10/51 |
| North Dakota | | | | | | | |
| Dickinson | 7,469 | | | S | 0.0 | 1.0 | 7/52 |
| Fargo | 37,982 | | D | | 0.15 | 1.0 | 7/52 |
| Mandan | 7,270 | S | | | 0.5 | 1.1 | 10/52 |
| Northwood | 1,168 | S | | | 0.2 | 1.2 | 8/51 |
| Riverdale† | 2,500 | | | | 0.5 | 1.2 | 3/52 |
| Williston | 10,000 | | D | | 0.5 | 1.2 | 4/53 |
| Ohio | | | | | | | |
| Avon Lake | 4,342 | | | S | 0.1 | 1.0 | 8/51 |
| Canton | 117,213 | | | S | 0.1 | 1.0 | 2/52 |
| Meyers Lake | | | | | | | |
| Chesapeake† | 1,285 | | | | 0.2 | | 8/53 |
| Elyria | 30,307 | S | | | 0.2 | 1.0 | 12/53 |
| Glendale | 2,402 | S | | | 0.2 | 1.0 | 12/52 |
| Hamilton | 57,951 | | | S | 0.2 | 1.0 | 2/53 |
| Ironton | 18,825 | | | | 0.2 | 1.0 | 6/53 |
| Jackson | 6,504 | S | | | 0.1 | 1.0 | 11/53 |
| Lisbon | 3,293 | | | S | 0.2 | 1.0 | 8/51 |

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; W.D.—water district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder. A number in parentheses following the name of a city indicates the number of other communities served by it.

† Uses ammonium silicofluoride with solution feeder.

‡ Served by Huntington, W.Va.

TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|----------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Ohio (contd.) | | | | | | | |
| Mahoning, S.D. | 190,000 | | D | | 0.2 | 1.0 | 9/52 |
| Canfield | | | | | | | |
| Niles | | | | | | | |
| Youngstown | | | | | | | |
| Martins Ferry (+2) | 18,474 | | S | | 0.3 | 1.0 | 8/52 |
| McDonald | 1,858 | S | | | 0.1 | 1.0 | 10/53 |
| Medina | 5,097 | S | | | 0.1 | 1.0 | 12/53 |
| Portsmouth | 36,798 | S | | | 0.2 | 1.0 | 10/53 |
| Westerville | 4,112 | S | | | 0.2 | 1.0 | 6/51 |
| Wyoming | 5,582 | S | | | 0.1 | 1.0 | 11/53 |
| Oklahoma | | | | | | | |
| Altus | 9,735 | | | | | | 12/53 |
| Ardmore | 17,831 | | D | | 0.2- | 1.0 | 1/53 |
| Bartlesville | 19,262 | | D | | 0.0 | 1.0 | 6/52 |
| Clinton | 7,555 | | | | | | 12/53 |
| Guthrie | 11,500 | | D | | 0.0 | 1.0 | 11/52 |
| Mangum | 4,271 | | | | | | 12/53 |
| Nowata | 3,904 | | D | | 0.0 | 1.2 | 8/51 |
| Tulsa | 182,740 | | | | | | 8/53 |
| Oregon | | | | | | | |
| Astoria | 12,331 | | D | | 0.0 | 1.0 | 12/52 |
| Corvallis | 17,496 | | D | | 0.0 | 1.0 | 6/52 |
| Philomath | | | | | | | |
| Florence | 1,026 | S | | | 0.1 | 1.0 | 6/52 |
| Forest Grove | 4,343 | | D | | 0.0 | 1.0 | 10/52 |
| Gearhart | 568 | S | | | 0.0 | 1.0 | 7/51 |
| Pendleton | 11,701 | | D | | 0.2 | 1.0 | 12/52 |
| Salem Heights W.D. | 2,280 | S | | | 0.2 | 1.0 | 1/53 |
| Pennsylvania | | | | | | | |
| Brookville | 6,000 | | D | | | 1.2 | 9/51 |
| Easton (+7) | 55,000 | D | | | | 1.0-1.2 | 5/52 |
| Ebensburg | 5,000 | D | | | | 1.2 | 12/51 |
| Ford City | 6,500 | D | | | | 1.2 | 6/51 |
| Manorville | | | | | | | |
| Natrona (+2) | 14,000 | | D | | | 1.0-1.2 | 12/52 |
| New Castle (+5) | 58,000 | | | | | | 12/53 |
| Pittsburgh (+10) | 770,000 | | D | | | 1.0-1.2 | 12/52 |
| Ridgway | 6,500 | | D | | | 1.0-1.2 | 1/53 |
| Wilkinsburg (+20) | 210,000 | | D | | | | 1/53 |
| Rhode Island | | | | | | | |
| Bristol | 29,085 | | | | | | 7/52 |
| Barrington | | | | | | | |
| Warren | | | | | | | |

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; W.D.—water district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder. A number in parentheses following the name of a city indicates the number of other communities served by it.

TABLE 1 (contd.)—*Fluoridation Plants in the United States and Canada, Dec. 31, 1953**

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|------------------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Rhode Island (contd.) | | | | | | | |
| Cumberland | 7,000 | | | | | | |
| Newport | 40,864 | D | | | | | 8/53 |
| Middletown | | | | | | | |
| Providence | 380,104 | D | | | 0.1 | 1.0-1.2 | 8/52 |
| Cranston | | | | | | | |
| Johnston | | | | | | | |
| North Providence | | | | | | | |
| Smithfield | | | | | | | |
| Warwick | | | | | | | |
| South Carolina | | | | | | | |
| Cheraw | 4,836 | S | | | 0.1- | 1.0 | 7/53 |
| Fort Mill | 3,204 | | D | | 0.0 | 1.0 | 5/51 |
| Hartsville | 5,643 | S | | | 0.0 | 1.0 | 10/51 |
| Lancaster | 7,159 | | D | | 0.0 | 1.0 | 6/53 |
| Ninety Six | 3,000 | St | | | 0.0 | 1.0 | 8/50 |
| Orangeburg | 15,322 | | D | | 0.0 | 1.0 | 9/52 |
| Rock Hill | 24,172 | | D | | 0.0 | 1.0 | 3/52 |
| South Dakota | | | | | | | |
| Aberdeen | 21,011 | | D | | 0.3 | 1.0 | 3/51 |
| Mobridge | 3,798 | S | | | 0.5 | 1.0 | 3/52 |
| Vermillion | 3,804 | | D | | 0.8 | 1.0 | 9/52 |
| Watertown | 12,662 | | | | | | 12/53 |
| Tennessee | | | | | | | |
| Bristol | 16,721 | | D | | 0.0 | 0.8-1.0 | 7/52 |
| Brownsville | 4,012 | | D | | 0.0 | 0.8-1.0 | 6/51 |
| Chattanooga (P) (+5) | 162,440 | | D | | 0.0 | 0.8-1.0 | 9/52 |
| Cleveland | 12,445 | | D | | 0.0 | 0.8-1.0 | 3/52 |
| Cookeville | 6,900 | | D | | 0.0 | 0.8-1.0 | 12/52 |
| Cowan | 1,843 | | D | | 0.0 | 0.8-1.0 | 1/53 |
| Crossville | 2,270 | | D | | 0.0 | 0.8-1.0 | 3/53 |
| Germantown | 402 | | | | S | 0.0 | 0.8-1.0 |
| Lawrenceburg | 5,843 | | D | | 0.0 | 0.8-1.0 | 2/53 |
| Milan | 4,940 | D | | | 0.0 | 0.8-1.0 | 3/51 |
| Nashville (+2) | 173,359 | | D | | 0.0 | 0.8-1.0 | 2/53 |
| Oak Ridge | 30,229 | | | | | | 11/53 |
| Paris | 8,818 | | D | | 0.0 | 0.8-1.0 | 10/52 |
| Tiptonville | 1,945 | | D | | 0.0 | 0.8-1.0 | 12/52 |
| Union City | 7,632 | | D | | 0.0 | 0.8-1.0 | 5/53 |
| Winchester | 3,976 | | | | | | 11/53 |
| Texas | | | | | | | |
| Breckenridge | 6,605 | D | | | 0.2 | 1.2 | 4/51 |
| Corpus Christi | 108,053 | D | | | | | 4/50 |

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TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|-----------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Texas (contd.) | | | | | | | |
| Gonzales | 5,630 | D | | | 0.3 | 1.2 | 11/53 |
| Graham | 6,756 | D | | | 0.6 | 1.2 | 5/51 |
| Iowa Park | 2,115 | D | | | 0.3 | 1.0 | 6/51 |
| Marshall | 22,250 | D | | | 0.7 | 1.0 | 5/46 |
| Paris | 21,643 | | D | | 0.4- | 0.8-1.0 | 10/52 |
| Port Arthur (+3) | 57,377 | D | | | 0.2 | 1.0 | 8/53 |
| Temple | 30,000 | D | | | 0.3 | 1.0 | 6/51 |
| Tyler | 38,864 | D | | | 0.2 | 1.0 | 5/52 |
| Wellington | 3,308 | | S | | 0.6 | 1.0 | 6/51 |
| Wichita Falls | 67,709 | D | S | | 0.3 | 1.0 | 7/51 |
| Utah | | | | | | | |
| None | | | | | | | |
| Vermont | | | | | | | |
| Burlington | 35,000 | D | | | 0.0 | 1.0 | 7/52 |
| Virginia | | | | | | | |
| Arlington† | | | | | | | |
| Blackstone | 7,000 | S | | | | 1.0 | 1/53 |
| Charlottesville | 30,000 | | D | | 0.1 | 1.0 | 1/52 |
| Danville | 47,000 | | D | | 0.1 | 1.0 | 10/53 |
| Falls Church† | | | | | | | |
| Fredericksburg | 12,000 | | | | 0.1 | 1.0 | 11/52 |
| Fries (P) | 15,000 | S | | | 0.1 | 1.0 | 8/52 |
| Blair Addition | | | | | | | |
| Lynchburg (+2) | 51,227 | | D | | 0.1 | 1.0 | 9/51 |
| Norfolk (+3) | 300,000 | D | | | 0.1 | 1.0 | 8/52 |
| Portsmouth‡ (+7) | 95,778 | | | | 0.1‡ | 0.8-1.1 | 8/52 |
| Richmond (+3) | 245,310 | | D | | 0.1 | 1.0 | 11/52 |
| Winchester | 13,841 | § | D | | 0.1 | 1.0 | 11/52 |
| Washington | | | | | | | |
| Clarkston (P) | 5,617 | | D | | 0.0 | 1.0 | 1/52 |
| Kennewick | 10,085 | D | | | trace | 1.0 | 12/50 |
| Norwood Village | 205 | S | | | trace | 1.0 | 2/52 |
| West Virginia | | | | | | | |
| Fairmont | 39,500 | | | | | | 10/53 |
| Grant Town | | | | | | | |
| Rivesville | | | | | | | |
| Huntington (P) (+2) | 86,353 | | D | | | 1.0 | 3/53 |
| Logan (P) | 5,079 | | | | | 1.0 | 4/53 |
| Matewan | 3,100 | S | | | | 1.0 | 2/53 |
| Parkersburg | 29,684 | | D | | | 1.0 | 8/53 |
| Ripley | 1,813 | S | | | | 1.0 | 4/51 |

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† Served by District of Columbia.

‡ Mixes surface supply with well water containing 5 ppm natural fluoride.

§ Used NaF prior to October 1953.

TABLE 1 (contd.)—*Fluoridation Plants in the United States and Canada, Dec. 31, 1953**

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|-------------------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| West Virginia (contd.) | | | | | | | |
| Sistersville | 2,313 | S | | | | 1.0 | 8/53 |
| Weirton | 24,005 | | D | | 0.7— | 1.0 | 4/51 |
| Wheeling (+4) | 64,400 | | D | | 0.7— | 1.0 | 10/49 |
| Williamson | 8,624 | S | | | | 1.0 | 6/53 |
| Williamstown | 3,837 | S | | | | 1.0 | 7/52 |
| Wisconsin | | | | | | | |
| Alma | 1,068 | S | | | 0.1 | 1.2 | 3/52 |
| Amery | 1,625 | S | | | 0.1 | 1.2 | 2/52 |
| Antigo | 9,902 | D | | | 0.1 | 1.1 | 6/49 |
| Appleton (+3) | 36,135 | | D | | 0.2 | 1.0 | 10/50 |
| Argyle | 702 | S | | | 0.1 | 1.0 | 8/53 |
| Ashland | 10,640 | | D | | 0.2 | 1.2 | 10/49 |
| Athens | 823 | S | | | 0.1 | 1.1 | 3/51 |
| Baraboo | 7,414 | | D | | 0.1 | 1.2 | 5/49 |
| Lyons | | | | | | | |
| Beaver Dam | 11,867 | | D | | 0.1 | 1.2 | 3/51 |
| Belleville | 735 | S | | | 0.1 | 1.0 | 8/51 |
| Beloit (P) | 29,590 | | D | | 0.1 | 1.0 | 4/49 |
| Berlin | 4,693 | S | | | 0.1 | 1.2 | 10/51 |
| Black River Falls | 2,824 | | D | | 0.2 | 1.2 | 5/53 |
| Blair | 873 | S | | | 0.2 | 1.3 | 7/51 |
| Bloomer | 2,556 | S | | | 0.1 | 1.0 | 8/50 |
| Boscobel | 2,347 | | D | | 0.1 | 1.2 | 3/52 |
| Cambridge | 552 | S | | | 0.1 | 1.1 | 6/51 |
| Cedar Grove | 1,010 | S | | | 0.65 | 1.2 | 2/52 |
| Columbus | 3,250 | | D | | 0.1 | 1.3 | 8/50 |
| Cottage Grove | 372 | S | | | 0.1 | 1.1 | 3/53 |
| Crestwood S.D. | 1,100 | S | | | 0.1 | 1.1 | 10/50 |
| Cuba City | 1,333 | S | | | 0.1 | 1.2 | 5/53 |
| Darlington | 2,174 | S | | | 0.1 | 1.2 | 8/53 |
| De Forest | 805 | | | S | 0.1 | 1.1 | 8/52 |
| Delaven | 4,007 | S | | | 0.1 | 1.3 | 11/53 |
| Dodgeville | 2,532 | | D | | 0.1 | 1.2 | 5/53 |
| Eagle River | 1,469 | | | S | 0.15 | 1.2 | 6/51 |
| Eau Claire | 36,058 | D | | | 0.15 | 1.2 | 1/51 |
| Edgar | 705 | S | | | 0.1 | 1.0 | 11/49 |
| Edgerton | 3,507 | | D | | 0.1 | 1.3 | 10/50 |
| Elkhorn | 2,935 | S | | | 0.3 | 1.0 | 4/48 |
| Evansville | 2,531 | | D | | 0.1 | 1.0 | 3/50 |
| Fond du Lac | 29,936 | | D | | 0.4 | 1.1 | 7/50 |
| Fort Atkinson | 6,280 | S | | | 0.1 | 1.0 | 12/49 |
| Galesville | 1,193 | S | | | 0.25 | 1.2 | 9/51 |
| Gillett | 1,410 | | | S | 0.1 | 1.2 | 6/53 |
| Hartford | 4,549 | S | | | 0.3 | 1.2 | 1/50 |
| Hayward | 1,577 | | | S | 0.1 | 1.1 | 6/51 |
| Horicon | 2,664 | S | | | 0.35 | 1.1 | 5/52 |

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TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|---------------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Wisconsin (contd.) | | | | | | | |
| Janesville | 24,899 | S | | | 0.1 | 1.1 | 2/49 |
| Lake Geneva | 4,300 | | D | | 0.2 | 1.1 | 5/51 |
| Lodi | 1,416 | | | S | 0.1 | 1.2 | 2/52 |
| Madison† (+8) | 107,580 | | | | 0.1 | 1.0 | 6/48 |
| Marinette | 14,178 | | D | | 0.2 | 1.0 | 3/51 |
| Marshfield | 12,394 | | D | | 0.2 | 1.1 | 10/50 |
| Mayville | 3,010 | S | | | 0.25 | 1.0 | 9/50 |
| Mazomanie | 962 | S | | | 0.1 | 1.4 | 9/51 |
| Menasha | 12,385 | | D | | 0.25 | 1.1 | 8/50 |
| Menomonee Falls | 2,469 | | | S | 0.4 | 1.3 | 9/51 |
| Middleton | 2,260 | S | | | 0.1 | 1.2 | 6/50 |
| Middleton S.D. | | | | | | | |
| Milton | 2,653 | | | S | 0.1 | 1.2 | 10/53 |
| Milton Junction | | | | | | | |
| Milwaukee (+6) | 720,429 | | D | | 0.2 | 1.0 | 7/53 |
| Mineral Point | 2,284 | | | S | 0.1 | 1.2 | 11/52 |
| Mosinee | 1,453 | | | S | 0.1 | 1.0 | 3/53 |
| Mount Horeb | 1,716 | | | S | 0.1 | 1.2 | 2/52 |
| Mukwonago | 1,207 | S | | | 0.3 | 1.0 | 5/49 |
| Neenah | 12,437 | | D | | 0.15 | 1.0 | 3/50 |
| New Glarus | 1,224 | S | | | 0.1 | 1.2 | 2/52 |
| New Holstein | 1,831 | | | S | 0.1 | 1.0 | 9/53 |
| Oconomowoc | 5,345 | | D | | 0.1 | 1.1 | 12/53 |
| Oregon | 1,341 | S | | | 0.1 | 1.1 | 2/50 |
| Orfordville | 543 | | | S | 0.1 | 1.0 | 9/51 |
| Osceola | 700 | S | | | 0.1 | 1.0 | 8/53 |
| Oshkosh | 41,084 | | D | | 0.2 | 1.1 | 1/50 |
| Phillips | 1,775 | S | | | 0.1 | 1.1 | 11/50 |
| Platteville | 5,751 | | D | | 0.1 | 1.2 | 10/51 |
| Port Washington | 4,755 | | D | | 0.1 | 1.3 | 9/50 |
| Portage | 7,334 | S | | | 0.35 | 1.2 | 3/51 |
| Poynette | 969 | S | | | 0.1 | 1.0 | 10/52 |
| Prairie du Sac | 1,402 | | | S | 0.1 | 1.0 | 10/51 |
| Racine (+3) | 71,843 | | D | | 0.1 | 1.0 | 3/50 |
| Reedsburg | 4,072 | | D | | 0.1 | 1.1 | 2/50 |
| Rhineland | 8,774 | | | S | 0.1 | 1.1 | 5/50 |
| Rice Lake | 6,898 | S | | | 0.1 | 1.1 | 1/52 |
| Richland Center | 4,608 | | D | | 0.1 | 1.2 | 12/49 |
| Ripon (P) | 5,619 | | D | | 0.1 | 1.4 | 6/51 |
| Sheboygan | 45,964 | D | | | 0.1 | 1.1 | 2/46 |
| Sheboygan Falls | | | | | | | |
| Shell Lake | 954 | S | | | 0.1 | 1.0 | 5/52 |
| Soldiers Grove | 781 | S | | | 0.1 | 1.0 | 1/50 |
| South Milwaukee | 12,855 | S | | | 0.1 | 1.1 | 6/52 |
| Sparta | 5,893 | | | S | 0.15 | 1.1 | 10/51 |
| Spooner | 2,597 | | | S | 0.1 | 1.3 | 5/52 |
| Spring Green | 1,064 | | | S | 0.1 | 1.2 | 12/51 |

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; W.D.—water district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder. A number in parentheses following the name of a city indicates the number of other communities served by it.

† Uses HF with oil displacement type feeder.

TABLE 1 (contd.)—Fluoridation Plants in the United States and Canada, Dec. 31, 1953*

| Location Served | Population Served | Chemical Used | | | Natural F ppm | F Residual Maintained ppm | Date Installed |
|---------------------------|-------------------|---------------|----------------------------------|---------------------------------|---------------|---------------------------|----------------|
| | | NaF | Na ₂ SiF ₆ | H ₂ SiF ₆ | | | |
| Wisconsin (contd.) | | | | | | | |
| Stoughton | 4,833 | | D | | 0.1 | 1.2 | 9/49 |
| Sun Prairie | 2,263 | | D | | 0.1 | 1.2 | 3/50 |
| Tomahawk | 3,534 | | | S | 0.1 | 1.1 | 6/51 |
| Trempealeau | 645 | S | | | 0.1 | 1.0 | 11/52 |
| Two Rivers | 10,243 | | D | | 0.1 | 1.2 | 5/53 |
| Watertown | 12,417 | | D | | 0.15 | 1.2 | 12/50 |
| Waunakee | 1,042 | | D | | 0.1 | 1.0 | 4/51 |
| Waupun | 6,725 | | D | | 0.1 | 1.2 | 11/50 |
| Wausau | 30,414 | | D | | 0.1 | 1.1 | 9/52 |
| West Bend | 7,888 | | D | | 0.1 | 1.0 | 8/50 |
| Barton | | | | | | | |
| Whitehall | 1,379 | S | | | 0.5 | 1.1 | 6/51 |
| Wisconsin Rapids | 13,496 | D | | | 0.1 | 1.2 | 1/51 |
| Wonewoc | 961 | S | | | 0.1 | 1.0 | 3/53 |
| Wyoming | | | | | | | |
| Laramie | 15,581 | | D | | 0.2 | 1.0 | 5/52 |
| Sinclair (P) | 604 | | D | | 0.3 | 1.2 | 1/52 |
| CANADA | | | | | | | |
| Ontario | | | | | | | |
| Brantford | 45,000 | D | | | | 1.0 | 6/45 |
| Brantford Twp. | | | | | | | |
| Chalk River | 2,800 | | † | | | 1.0 | 12/52 |
| Deep River | | | | | | | |
| Fort Erie | 8,500 | † | | | | 1.0 | 1/52 |
| Oshawa | 42,000 | | † | | | 1.2 | 2/53 |
| Sudbury | 60,000 | | † | | | 0.9 | 8/52 |
| McKim Twp. | | | | | | | |
| Thorold | 7,500 | † | | | | 1.0 | 2/52 |
| Thorold Twp. | | | | | | | |
| Saskatchewan | | | | | | | |
| Assiniboia | 2,000 | † | | | | 1.0 | 5/53 |
| Moose Jaw | 24,000 | † | | | | 1.2 | 12/52 |

* Key to symbols and abbreviations in table: P—privately owned utility; S.D.—sanitary district; W.D.—water district; D—dry-feed equipment; S—solution- or slurry-feed equipment (slurry feed is applicable only to sodium silicofluoride installations); St—saturator type feeder. A number in parentheses following the name of a city indicates the number of other communities served by it.

† Type of feeder not reported.

tory) in the United States. For 20-25 per cent byproduct material used at water works within easy trucking distance of the producer, the price is considerably lower. Ammonium silicofluoride, in quantities greater than 5 tons, sells for 12 cents per pound; in amounts less than 1 ton, the price is

14 cents per pound (both prices fob Camden, N.J.).

Dust Control

It has been established by tests of the air in the vicinity of fluoride feeding equipment, during normal operation and while filling hoppers or charg-

ing solution tanks, that certain precautions are advisable to prevent inhalation of fluoride dust by plant operators. Consequently, special consideration should be given to dust tightness in the purchase of dry-feed equipment. Provision should be made for the proper transfer of dry fluorine compounds from shipping containers to storage bins or hoppers, in order to minimize the quantity of dust that may enter the room.

tered effectively and discharged to the outside of the building.

2. When material is to be dumped through an opening in a closed hopper, bin, or solution tank from bags, drums, or barrels, an exhaust fan with a dust filter should be employed. The fan should have a capacity sufficient to provide a velocity of 200 fpm into the opening through which the material is dumped, and should be installed in the exhaust duct so that the dust filter en-

TABLE 2
Summary of Fluoridation Plant Census, 1945-53

| Year | United States | | | | Canada | |
|------|--------------------|----------------------|--------------------|-------------------------|----------------------|-------------------------|
| | States With Plants | No. of Water Systems | Communities Served | Total Population Served | No. of Water Systems | Total Population Served |
| 1945 | 3 | 3 | 3 | 209,000 | 1 | 40,000 |
| 1946 | 7 | 9 | 9 | 302,000 | 1 | 40,000 |
| 1947 | 9 | 11 | 11 | 388,000 | 1 | 40,000 |
| 1948 | 9 | 13 | 18 | 493,000 | 1 | 40,000 |
| 1949 | 11 | 27 | 33 | 777,000 | 1 | 40,000 |
| 1950 | 16 | 62 | 78 | 1,384,000 | 1 | 50,000 |
| 1951 | 37 | 172 | 240 | 4,410,000 | 1 | 50,000 |
| 1952 | 43* | 354 | 447 | 12,590,000 | 5 | 128,000 |
| 1953 | 43* | 480 | 842 | 15,900,000 | 8 | 192,000 |

* Plus District of Columbia.

It is not possible for this committee to establish the amount of dust protection equipment required. Information of this nature can best be gained by consulting the various state industrial-hygiene divisions. The proper method of material handling depends on the type of equipment and material and the size of the installation. Approval by state health authorities should be obtained in every instance. The following alternatives are advocated:

1. Vacuum pneumatic equipment may be provided for drawing powdered material from shipping containers to closed storage hoppers, the exhaust air from the system being fil-

closure and the hopper will be under negative pressure. The filter medium, ducts, and fan must be cleaned at intervals to maintain the efficiency and capacity of the evacuating system.

3. A dust-tight receptacle, forming an integral part of the chemical feeder, can be used to enclose a bag or drum of fluoride compound so that, when the container is emptied into the hopper, bin, or solution tank, no dust will escape.

4. When the material is received in drums, a special cover, fitted with a sliding gate, may be attached to the top of the drum in place of the shipping cover; the cover should be so designed

that, after the drum has been hoisted and inverted over the hopper by a suitable device, the cover will attach to the hopper in a dust-tight manner; then the sliding gate may be opened to permit the material to fall into the hopper.

Any other device or method that enables the material to be handled without release of dust will no doubt be approved. Provision should also be made for the disposal of empty bags, drums, and barrels, either by burning or by some other acceptable means of minimizing exposure to fluoride dusts.

Dry-Feed Problems

In general, relatively little mechanical trouble has been encountered in handling and feeding sodium fluoride. About 30 per cent of the organizations queried experienced some difficulty with lumping after prolonged storage or when the material came in bags that failed to keep it moisture free. In Canada, a report of trouble with supposedly "damp" sodium fluoride obtained locally was investigated. It was found that the chemical actually contained less moisture than imported

TABLE 3
Fluoride Chemicals and Type of Equipment, 1952-53

| Chemical | Total Plants Reporting | | Solution-Feed Units | | Dry-Feed Units | |
|--|------------------------|------|---------------------|------|----------------|------|
| | 1952 | 1953 | 1952 | 1953 | 1952 | 1953 |
| Sodium silicofluoride, Na_2SiF_6 | 176 | 222† | 2 | 13 | 174 | 216 |
| Sodium fluoride, NaF | 146* | 177‡ | 84 | 117 | 63 | 62 |
| Fluosilicic acid, H_2SiF_6 | 32 | 36 | 32 | 36 | | |
| Ammonium silicofluoride, $(\text{NH}_4)_2\text{SiF}_6$ | 1 | 2 | 1 | 2 | | |
| Hydrofluoric acid, HF | 1 | 1 | 1 | 1 | | |

* One system used both dry and solution feeders.

† Seven systems used both dry and solution feeders.

‡ Two systems used both dry and solution feeders.

Broken or leaking bags or drums should immediately be repaired, when feasible, or else emptied at once into storage hoppers. A metal wheelbarrow is convenient for handling leaky bags. A wet mop or vacuum cleaner should be used to remove any fluoride dust that may accumulate. Dust elimination equipment appears to be unnecessary when using a small container or scoop to transfer granular or crystalline fluoride compounds if none of the material will pass a 200-mesh screen and not more than 15 per cent will pass a 100-mesh screen.

material which was satisfactory in this respect. On further study, it was learned that the local product was highly alkaline, while the imported material was neutral. When the alkaline reaction was corrected in the manufacturing process, the difficulty was eliminated.

No organization reported arching or flooding problems with sodium fluoride, but this material is generally classed as free flowing, and many feeders are equipped with antiflooding devices. It is not common practice to purchase it under a definite screen size

specification, except to request powdered or granular material.

In contrast, considerable mechanical trouble has been experienced in handling sodium silicofluoride, particularly in plants using large quantities. Forty-five per cent of the organizations queried reported some arching in

specifications, and these vary from a requirement for 400-mesh material to one for material not more than 10 per cent of which will pass a 325-mesh sieve. The following specifications seem practical: 100 per cent to pass a 40-mesh sieve; 95 per cent to pass a 100-mesh sieve; and not less than 5

TABLE 4
Solubility Rates

| | Compound | | | | | |
|----------------------------------|----------------------------------|-------------------------------------|------|------|------|------|
| | A | B | C | D | E | F |
| Screen Sizes | | | | | | |
| Retained on | Amount Retained— <i>per cent</i> | | | | | |
| 60 mesh | 3 | | | 1 | 2 | 1 |
| 100 mesh | 29 | 2 | 3 | 6 | 3 | 5 |
| 200 mesh | 56 | 57 | 50 | 39 | 39 | 34 |
| 325 mesh | 11 | 24 | 32 | 25 | 25 | 23 |
| Passed 325 mesh | 1 | 17 | 15 | 29 | 32 | 37 |
| Rate of Solution (35°F) | | | | | | |
| Concentration <i>per cent</i> | Time <i>min</i> | Amount Undissolved— <i>per cent</i> | | | | |
| 0.2 | 1 | | | | | |
| | 3 | 43.7 | 25.6 | 25.0 | 20.3 | 21.3 |
| | 5 | 25.8 | 13.8 | 9.8 | 11.6 | 12.2 |
| | 10 | 10.0 | 1.4 | 0.91 | 2.9 | 3.0 |
| 0.4 | 1 | | | | | |
| | 3 | | | 36.1 | 32.6 | 30.3 |
| | 5 | | | 26.1 | 25.1 | 27.3 |
| | 10 | | | 14.5 | 13.1 | 11.9 |
| | 20 | | | 1.8 | 1.9 | 1.4 |

feeder, storage, or auxiliary hoppers; 40 per cent noted some clogging in the feeders; and 55 per cent had trouble due to lumping. Approximately 20 per cent of the organizations have rejected some material because of dampness.

Only about 40 per cent purchase sodium silicofluoride under screen size

or more than 30-35 per cent to pass a 325-mesh sieve. This matter is given further consideration in the next section of this report.

Fine material causes arching and some clogging of the feeders. Arching is usually overcome by the use of vibrators. Relatively coarse material may result in some lumping; screening

to break up the lumps seems to be a successful solution.

Warming the room or putting a light bulb in the hopper, where practical, has aided in overcoming dampness, but, in general, any material showing excessive dampness should be rejected. There seems to be no serious trouble in maintaining correct feed rates, although about 20 per cent of the organizations queried experienced occasional trouble when lumpy or damp material was encountered.

Sodium Silicofluoride Solution Problems

A survey of approximately 50 typical sodium silicofluoride installations.

TABLE 5
Effect of Temperature and Concentration on Solubility of Compound D

| Temperature °F | Stirring Time min | Amount Undissolved—per cent | | |
|-------------------|-------------------------|-----------------------------|---------------|---------------|
| | | 0.4% Conc. | 0.2% Conc. | 0.1% Conc. |
| 77 | 1 | 12.7 | 7.5 | 0 |
| | 3 | 1.6 | 0.3 | 0 |
| | 5 | 0 | 0 | 0 |
| 35 | 1 | | | 41.0 |
| | 3 | 32.6 | 20.3 | 17.2 |
| | 5 | 25.1 | 11.6 | 7.8 |
| | 10 | 13.1 | 2.9 | 0 |
| | 20 | 1.9 | 0 | |

was made to determine the nature and extent of the problems connected with the application of this material. The replies indicate that water varying in temperature from 32° to 80°F is used for dissolving this chemical, with essentially minor insolubility problems. The difficulty can, however, be serious under some circumstances. For example, the silicofluoride solution at one installation must be introduced through

a hose into the well itself. The amount of water that can be sent down the well in this manner is limited and there has been frequent trouble from plugging. In this instance, the hardness of the water was not considered to be the cause, although hard water has been a contributing factor elsewhere. It was generally agreed that some insolubility does occur below 40°F.

The solution tanks of the installations surveyed are made of a variety of materials, including steel, stainless steel, cast iron, galvanized iron, tar-coated wood, concrete (sheet-metal lined), Monel metal, and porcelain. The steel tanks are usually painted or lined with rubber or plastic. All of these materials have generally proved satisfactory. In one instance, a cast-

TABLE 6
Solubility of Selected Fractions

| Concentration per cent | Particle Size of Fraction | Amount Undissolved per cent |
|---------------------------|------------------------------|-----------------------------------|
| 0.4 | 100 mesh | 49.5 |
| | 100-140 mesh | 32.5 |
| | 140-200 mesh | 15.7 |
| 0.2 | 100 mesh | 43.1 |
| | 100-140 mesh | 18.6 |
| | 140-200 mesh | 5.3 |

iron pot gave trouble and was replaced by a ceramic tank. At another installation, a rubber-lined steel tank had to be patched at the water line and on the bottom after 1½ years' service.

The solution lines consist of rubber, hard rubber, plastic, galvanized iron, rubber-lined steel, stainless steel, or copper. A number of plants reported serious corrosion of galvanized-iron pipe or fittings. Corrosion of brass, iron, and steel also led some installations to change to rubber or plastic.

To ascertain the effects of screen size and temperature on solubility, a laboratory study was conducted by a member of this committee, R. W. Ockershausen, Technical Service, General Chemical Div., Allied Chemical and Dye Corp., Edgewater, N.J. Six compounds, with screen sizes as shown, were tested for rate of solution at two concentrations (Table 4). The effects of various temperatures and concentra-

1. Sodium silicofluoride coarser than Product *B* (Table 4) will not dissolve at reasonable rates at 35°F.

2. There is a tremendous difference in the rate of solution in water at 35°F and 77°F, with the rate greatly retarded in the cold water.

3. Probably no more than 10 per cent of the material should be coarser than 100 mesh to maintain satisfactory rates of solution.

TABLE 7
Water Supplies With Natural Fluoride in Excess of 1.5 ppm

| State | No. of Places | Population Served | State | No. of Places | Population Served |
|-------------|---------------|-------------------|----------------|---------------|-------------------|
| Alabama | 5 | 8,038 | Missouri | 11 | 47,875 |
| Arizona | 36 | 77,088 | Montana | 5 | 3,281 |
| Arkansas | 1 | 2,389 | Nevada | 4 | 1,553 |
| California | 3 | 3,069 | New Jersey | 4 | 16,042 |
| Colorado | 16 | 57,296 | New Mexico | 20 | 26,333 |
| Connecticut | 1 | 400 | New York | 2 | 523 |
| Florida | 6 | 38,093 | North Carolina | 3 | 7,363 |
| Georgia | 1 | 1,885 | North Dakota | 56 | 58,152 |
| Idaho | 5 | 4,019 | Ohio | 30 | 41,376 |
| Illinois | 38 | 112,764 | Oklahoma | 16 | 72,700 |
| Indiana | 14 | 47,967 | Oregon | 3 | 979 |
| Iowa | 55 | 174,878 | South Carolina | 6 | 11,607 |
| Kansas | 12 | 17,043 | South Dakota | 69 | 48,523 |
| Kentucky | 1 | 1,545 | Tennessee | 1 | 3,571 |
| Louisiana | 8 | 46,718 | Texas | 135 | 424,628 |
| Maryland | 4 | 2,418 | Utah | 3 | 4,498 |
| Michigan | 3 | 8,733 | Virginia | 24 | 18,685 |
| Minnesota | 7 | 2,921 | Wisconsin | 9 | 82,638 |
| Mississippi | 10 | 5,095 | Wyoming | 4 | 4,161 |

tions on the solubility of one of these compounds are indicated in Table 5.

In another experiment, a typical product was screened to obtain three fractions of different particle sizes: [1] up to and including 100 mesh; [2] 100-140 mesh; [3] 140-200 mesh. After 5-min stirring at 35°F, the solubility of these fractions was found to be as shown in Table 6.

It may be concluded from these tests that:

4. Dissolving chambers and dilution lines should be sized to provide a maximum solution strength of 0.2 per cent; preferably, solutions should be more dilute.

5. A minimum of 5 min of detention or solution time in the dissolving tank at maximum rates of pumpage appears satisfactory, as the periods of lowered solubility occur in the winter, when pumpage rates are generally lower. At such times as much as 10 min, or

possibly more, of detention time should be provided.

Recent Developments in Fluoridation Equipment

The fluoridation of a water supply is essentially the same as, and no more involved than, any other water treatment process. Equipment considered especially suited for fluoridation consists of those standard items which feature accuracy, dust control, and continuous recording of the amount of chemical used. To meet these requirements, manufacturers have introduced a line of gravimetric feeders to provide the advantages of this type of equipment for small installations. A loss-of-weight recorder, to function in con-

junction with a volumetric feeder, has also been placed on the market, along with a new line of dust collectors. A fluoride concentration recording unit has been installed at one plant to serve as a field demonstration of the practicability of conductivity measurement for recording and determining the fluoride added.

Natural Fluoride

Table 7 lists the population served by water supplies containing naturally occurring fluoride in concentrations greater than 1.5 ppm. There are 631 communities (in 38 states) so served, with a total population of approximately 1,500,000. Table 1 shows the natural-fluoride content, if any, at cities with controlled fluoridation.

Waterborne Fluorides and Mortality

In the May 1954 issue of *Public Health Reports* (Vol. 69, p. 450), Hagan, Pasternack, and Scholz describe the results of a study of 1949-50 mortality rates in 64 cities in sixteen states. Half of these cities had water supplies with a fluoride content of 0.70 ppm or more; in the remainder, the fluoride content was 0.25 ppm or less.

The authors concluded that the data for the two groups of cities show "no statistically significant difference" in mortality rates from all causes or specifically from heart disease, cancer, intracranial lesions, nephritis, or cirrhosis of the liver.

Utility of Butterfly Valves

By Gerald E. Arnold

A contribution to the Journal by Gerald E. Arnold, Gen. Supt., Water Dept., Philadelphia.

IN connection with the publication of the AWWA standards for butterfly valves (this issue, page 943), a few comments on the general characteristics of these valves and their uses may be in order.

The butterfly valve is not new to water works operation, but has been used for many years under certain circumstances. Owing to recent technological advances that have improved the quality of the valves and their general usefulness, their employment in water works service is becoming more generally widespread. One of the principal factors contributing to this increased use is the rubber seat, a fairly recent development, which enables a butterfly valve to be shut droptight. With the metal seats formerly utilized, the necessary clearance between the disc and seat made it impossible to obtain completely tight shutoff. The compressibility of the rubber permits the disc to be closed tight against the seat.

The principal advantages of butterfly valves over other types are lightness in weight, smaller space requirements, ease of operation, and, in many instances, cheaper purchase price. One disadvantage is that a fully opened water passage is not possible when the valve is in the open position; another is that, if extensive repairs are needed, it is more frequently necessary to re-

move the entire valve from the line than would be true for a gate valve, although the latter may also have to be completely removed in the event of body troubles.

With regard to space saving, a 24-in. 125-psi gate valve, for example, requires 24 in. for insertion, while a butterfly valve needs only 18 in. No bypass valve is required on a butterfly valve.

As for ease of operation, the butterfly valve is practically balanced against pressure, in that, when the valve is fully closed, half the disc tends to open while the other half tends to close, owing to the water pressure against the disc, provided that the disc is not at a full 90-deg angle to the axis of flow. In the partly opened position, the same situation prevails, and, from barely open until fully open, forces affecting the disc are partially balanced. In moving a butterfly valve from one position to another, it is necessary only to rotate the shaft horizontally, no longitudinal movement being required as in some other types of valve. Thus, in comparison with the latter, the stuffing box around the butterfly valve stem takes a smaller amount of motion, is easier to keep tight, and produces less friction during the movement of the stem.

Several types of operators may be used with butterfly valves. For small

valves under low pressure, a simple lever, manually operated, may be equipped with a ratchet to hold the valve in any one of several desired positions. The lever may be attached to a worm gear that can be turned with a crank or a chain sprocket. More complicated and higher-pressure valves can be operated through a reduction-gear box connected to a handwheel or to any other turning device powered by electricity, compressed air, or the like. Butterfly valves may also be connected by a link-and-lever arrangement to a pneumatic or hydraulic cylinder. The diameter and length of such a cylinder would be smaller than for a gate valve of similar size. An indicator showing the position of the disc may be located at any convenient place on the valve or operating mechanism. The valves may be remotely controlled through hydraulic, electric, or pneumatic devices.

The butterfly valve is suitable for use in throttling operations. Partly open and rigidly held in position, it will restrict the flow of water effectively without serious damage to the valve itself. In a partly open position, the balanced pressures on the upstream side of the disc tend to keep it in place. Water may flow around both sides of the disc, the turbulence assisting the reduction of flow. In the fully open position, there is some interference with flow because the disc is centered in the valve. Owing to the streamlined shape, this factor is not serious except at very high velocities.

Head-loss curves for butterfly valves in all positions are available from the manufacturers.

Butterfly Valve Inserts

Philadelphia recently installed butterfly valve inserts in the bodies of several broken 48-in. gate valves that had been in service for many years. In effecting repairs, the bonnet was taken off the gate valve and the internal parts were entirely removed from the body. An inserting device was made to fit inside the body of the gate valve. It consisted of a ring of about the same dimensions as the outside of the old gate valve discs. Within the center of the ring, a butterfly valve was placed so that the stem was vertical. The inserting device was lowered into the body and pushed against one of the old seat rings by a series of jack screws, affecting a seal against an O-ring gasket. A cover plate was then placed on the valve body in lieu of the bonnet, and the operator mechanism was mounted on the plate. Although the original 48-in. valve was reduced to an effective size of about 42 in. by the inserting mechanism, the result was a satisfactorily operating valve inside an old gate valve that could not be repaired. Operating conditions did not allow sufficient time to remove the entire gate valve body from the line. The butterfly valve inserting mechanism, however, proved very successful in restoring the line to usefulness. Such applications indicate the utility of butterfly valves in water works service.

American Water Works Association

Tentative

Standard Specifications

for

RUBBER-SEATED BUTTERFLY VALVES

These "Specifications for Rubber-seated Butterfly Valves" are based upon the best known experience and are intended for use under conditions in which the maximum line velocity will not exceed 16 fps. Torque requirements for operation increase rapidly with increase in velocity. In specifying valves to be purchased under these standards, care must be exercised by the responsible engineer to ascertain that operating conditions fall within the scope of the specifications.

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AMERICAN WATER WORKS ASSOCIATION
Incorporated

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**Tentative Standard Specifications for
Rubber-seated Butterfly Valves**

Sec. 1—Scope

1.1. These specifications cover cast-iron and steel, flanged-end, rubber seat, tight-closure butterfly valves, 3-72 in. in size, for maximum shutoff pressures of 125 psi and maximum line velocities of 16 fps, together with torque requirements for operation. The valves specified are suitable for frequent operation, operation after long periods of idleness, and operation in a throttled position; the valves are suitable for operation at water temperatures up to 190°F.

1.2. These specifications cover valves designed for the shutoff pressure and line velocities shown in Table 1. Valves in each class shall be designed for opening and closing against the shutoff pressure specified with pipeline velocities not exceeding the velocity specified for each class. (Pipeline velocity is defined as water flow, in cubic feet per second, divided by the internal area of the pipe, in square feet.)

1.3. These specifications are not intended to cover valves for installations where service conditions exceed the shutoff pressures and line velocities stated in Table 1 or where the water involved has a pH of less than 5 or a temperature in excess of 190°F. Such conditions are beyond the intended scope of these specifications and require special consideration in matters of design and construction.

1.4. Torque requirements increase rapidly with increase in velocity. Conditions under which valves are to be

operated must be carefully evaluated to determine the maximum velocity that might result either from operating conditions or a line break. For valves purchased under these specifications, the line velocities must not exceed those shown in Table 1.

Sec. 2—Information to Be Supplied by Purchaser

In placing orders for valves to be manufactured in accordance with

TABLE 1
Classes of Valves

| Class | Shutoff Pressure psi | Max. Pipeline Velocity fps |
|--------|-------------------------|-------------------------------|
| 25-8 | 25 | 8 |
| 25-16 | 25 | 16 |
| 50-8 | 50 | 8 |
| 50-16 | 50 | 16 |
| 125-8 | 125 | 8 |
| 125-16 | 125 | 16 |

these specifications, purchasers should specify the following details:

- 2.1. Designation of AWWA specifications applying.
- 2.2. Size of valve.
- 2.3. Class of valve.
- 2.4. Quantity required.
- 2.5. Whether records of tests are to be furnished as specified under Sec. 4.3 of these specifications.
- 2.6. Type of operation required; that is, electric motor, air cylinder, water cylinder, oil cylinder, or manual.
- 2.7. pH of the water that the valve is expected to handle.

Sec. 3—Data to Be Furnished by Manufacturer

3.1. The manufacturer shall furnish certified drawings and material specifications of the equipment he is proposing to supply. The drawings shall

construction details, and materials used for all parts of the valve. All work shall be done and all valves shall be furnished in accordance with these certified drawings after they have been approved by the purchaser.

TABLE 2
Body and Flange Dimensions—Class 25-8 and 25-16 Valves

| Valve Size in. | Face to Face* in. | Cast Valves | | Fabricated Valves | |
|----------------|-------------------|-----------------------|--------------------------------|----------------------------|-------------------------------|
| | | Flange Thickness† in. | Min. Body Shell Thickness‡ in. | Min. Flange Thickness§ in. | Min. Body Shell Thickness in. |
| 3 | 5 | 1/8 | 0.37 | 1/2 | 1/4 |
| 4 | 5 | 1/8 | 0.40 | 1/2 | 1/4 |
| 6 | 5 | 1 | 0.43 | 1/8 | 1/4 |
| 8 | 6 | 1 1/4 | 0.46 | 1/8 | 1/4 |
| 10 | 8 | 1 3/8 | 0.50 | 1/8 | 1/4 |
| 12 | 8 | 1 1/4 | 0.54 | 1/8 | 1/4 |
| 14 | 8 | 1 1/8 | 0.54 | 1/4 | 1/4 |
| 16 | 8 | 1 7/8 | 0.58 | 1/4 | 1/4 |
| 18 | 8 | 1 15/16 | 0.63 | 1/4 | 1/4 |
| 20 | 8 | 1 11/16 | 0.66 | 1/4 | 1/4 |
| 24 | 8 | 1 1/4 | 0.74 | 1 | 1/2 |
| 30 | 12 | 2 1/8 | 0.87 | 1 | 1/2 |
| 36 | 12 | 2 1/8 | 0.97 | 1 1/8 | 1/2 |
| 42 | 12 | 2 1/8 | 1.07 | 1 1/4 | 1/2 |
| 48 | 15 | 2 1/4 | 1.18 | 1 1/8 | 1/2 |
| 54 | 15 | 3 | 1.30 | 1 1/2 | 1/2 |
| 60 | 15 | 3 1/8 | 1.39 | 1 1/2 | 1/2 |
| 66 | 18 | 3 1/8 | 1.625 | 1 1/2 | 1/2 |
| 72 | 18 | 3 1/8 | 1.75 | 1 1/2 | 1/2 |

* Includes rubber, if rubber extends over flange face.

† Conforms to ASA B16.1 for 125-psi cast-iron flanges; as an alternate, by request of purchaser, flange thickness conforming to ASA B16.2 for 25-psi cast-iron flanges may be furnished.

‡ Reference ASA A21.2, Class 50 cast-iron pit-cast pipe.

§ Reference AWWA C207, Class B steel hub flanges.

be in sufficient detail to show that the equipment proposed meets the specifications of the purchaser.

3.2. When required, the manufacturer shall furnish a statement of the total net assembled weight for each valve.

3.3. When required, the manufacturer shall submit for approval by the purchaser three sets of certified drawings, showing the principal dimensions,

3.4. The manufacturer shall furnish certification of tests, if required.

Sec. 4—Materials

4.1. *General.* All materials designated hereinafter, when used in valves produced under these specifications, shall conform to the specifications designated below for each material listed. When reference is made to American Standards Assn. (ASA), American So-

ciety for Testing Materials (ASTM), and other specifications as may be stipulated, the latest revision thereof shall apply.

4.2. Physical and chemical properties. The requirements of ASA, ASTM, or other specifications to

manufacturer. The records of such tests shall, if required by the purchaser, be made available to him.

Sec. 5—Valve Bodies and Flanges

5.1. Bodies of all valves shall be constructed with two flanges and shall

TABLE 3
Body and Flange Dimensions—Class 50-8 and 50-16 Valves

| Valve Size in. | Face to Face* in. | Cast Valves | | Fabricated Valves | |
|----------------|-------------------|-----------------------|--------------------------------|----------------------------|---------------------------------|
| | | Flange Thickness† in. | Min. Body Shell Thickness‡ in. | Min. Flange Thickness§ in. | Min. Body Shell Thickness in. |
| 3 | 5 | 1 $\frac{1}{8}$ | 0.37 | 1 $\frac{1}{8}$ | 1 |
| 4 | 7 | 1 $\frac{1}{8}$ | 0.40 | 1 $\frac{1}{8}$ | 1 |
| 6 | 8 | 1 | 0.43 | 1 | 1 $\frac{1}{8}$ |
| 8 | 8 $\frac{1}{2}$ | 1 $\frac{1}{8}$ | 0.46 | 1 $\frac{1}{8}$ | 1 $\frac{1}{8}$ |
| 10 | 15 | 1 $\frac{1}{16}$ | 0.50 | 1 $\frac{3}{16}$ | 1 $\frac{1}{16}$ |
| 12 | 15 | 1 $\frac{1}{8}$ | 0.54 | 1 $\frac{1}{4}$ | 1 $\frac{1}{8}$ |
| 14 | 16 | 1 $\frac{3}{8}$ | 0.58 | 1 $\frac{3}{8}$ | 1 $\frac{3}{8}$ |
| 16 | 16 | 1 $\frac{7}{16}$ | 0.63 | 1 $\frac{7}{16}$ | 1 $\frac{7}{16}$ |
| 18 | 16 | 1 $\frac{9}{16}$ | 0.68 | 1 $\frac{9}{16}$ | 1 $\frac{9}{16}$ |
| 20 | 18 | 1 $\frac{11}{16}$ | 0.71 | 1 $\frac{11}{16}$ | 1 $\frac{11}{16}$ |
| 24 | 18 | 1 $\frac{1}{2}$ | 0.80 | 1 $\frac{1}{8}$ | 1 $\frac{1}{8}$ |
| 30 | 22 | 2 $\frac{1}{8}$ | 0.94 | 2 $\frac{1}{8}$ | 1 $\frac{1}{8}$ |
| 36 | 22 | 2 $\frac{1}{8}$ | 1.13 | 2 $\frac{1}{8}$ | 1 $\frac{1}{8}$ |
| 42 | 24 | 2 $\frac{1}{8}$ | 1.16 | 2 $\frac{1}{8}$ | 1 $\frac{1}{8}$ |
| 48 | 26 | 2 $\frac{1}{8}$ | 1.37 | 2 $\frac{1}{8}$ | 1 $\frac{1}{8}$ |
| 54 | 28 | 3 | 1.51 | 3 | 1 $\frac{1}{8}$ |
| 60 | 30 | 3 $\frac{1}{2}$ | 1.62 | 3 $\frac{1}{2}$ | 1 |
| 66 | 34 | 3 $\frac{1}{2}$ | 1.80 | 3 $\frac{1}{2}$ | 1 $\frac{1}{8}$ |
| 72 | 36 | 3 $\frac{1}{2}$ | 2.00 | 3 $\frac{1}{2}$ | 1 $\frac{1}{4}$ |

* Includes rubber, if rubber extends over flange face.

† Reference ASA B16.1, 125-psi cast-iron flanges.

‡ Reference ASA A21.2, Class 100 cast-iron pit-cast pipe.

§ Reference AWWA C207, Class E steel hub flanges.

|| Sizes up to 24 in.—reference ASA B16.6, 150-psi steel pipe.

which reference is made elsewhere in this text shall govern the physical and chemical characteristics of the valve components.

4.3. Tests. Whenever valve components are to be made in conformance with ASA, ASTM, or other specifications that include test requirements or testing procedures, such requirements or procedures shall be met by the valve

have two hubs for shaft bearing housings, integral with the valve bodies. All valve flanges shall have a drilling layout in accordance with the standard drilling for ASA B16.1 cast-iron flanges. As an alternate, valves of Class 25-8 and Class 25-16 may, if requested by the purchaser, be furnished with flange drilling in accordance with ASA B16.2 standards for

25-psi cast-iron flanges. All valves shall have full-drilled holes through the body flanges; except that drilled and tapped holes in flanges of Class 25-8 and 25-16 valves are acceptable.

5.2. Valve body and flange dimensions for Class 25-8 and 25-16 valves shall be as specified in Table 2; for

Sec. 6—Valve Shafts

6.1. All valve shafts may consist of a one-piece unit extending completely through the valve disc or may be of the "stub shaft" type, which comprises two separate shafts inserted into the valve disc hubs.

TABLE 4
Body and Flange Dimensions—Class 125-8 and 125-16 Valves

| Valve Size in. | Face to Face* in. | Cast Valves | | Fabricated Valves | |
|----------------------|-------------------------|-----------------------------|--------------------------------------|----------------------------------|---------------------------------------|
| | | Flange Thickness† in. | Min. Body Shell Thickness‡ in. | Min. Flange Thickness§ in. | Min. Body Shell Thickness in. |
| 3 | 5 | 1 $\frac{1}{8}$ | 0.37 | 1 $\frac{1}{8}$ | 1 $\frac{1}{4}$ |
| 4 | 7 | 1 $\frac{1}{8}$ | 0.40 | 1 $\frac{1}{8}$ | 1 $\frac{1}{4}$ |
| 6 | 8 | 1 | 0.43 | 1 | 1 $\frac{1}{2}$ |
| 8 | 8 $\frac{1}{2}$ | 1 $\frac{1}{4}$ | 0.46 | 1 $\frac{1}{4}$ | 1 $\frac{1}{2}$ |
| 10 | 15 | 1 $\frac{3}{16}$ | 0.54 | 1 $\frac{7}{16}$ | 1 $\frac{1}{2}$ |
| 12 | 15 | 1 $\frac{1}{4}$ | 0.58 | 1 $\frac{1}{4}$ | 1 $\frac{1}{2}$ |
| 14 | 16 | 1 $\frac{1}{4}$ | 0.63 | 1 $\frac{1}{4}$ | 1 $\frac{1}{2}$ |
| 16 | 16 | 1 $\frac{7}{16}$ | 0.68 | 1 $\frac{7}{16}$ | 1 $\frac{1}{2}$ |
| 18 | 16 | 1 $\frac{1}{16}$ | 0.79 | 1 $\frac{1}{16}$ | 1 $\frac{1}{2}$ |
| 20 | 18 | 1 $\frac{1}{8}$ | 0.83 | 1 $\frac{1}{8}$ | 1 $\frac{1}{4}$ |
| 24 | 18 | 1 $\frac{1}{4}$ | 0.93 | 1 $\frac{1}{4}$ | 1 $\frac{1}{4}$ |
| 30 | 22 | 2 $\frac{1}{8}$ | 1.10 | 2 $\frac{1}{8}$ | 1 $\frac{1}{4}$ |
| 36 | 22 | 2 $\frac{1}{4}$ | 1.22 | 2 $\frac{1}{4}$ | 1 $\frac{1}{4}$ |
| 42 | 24 | 2 $\frac{1}{4}$ | 1.35 | 2 $\frac{1}{4}$ | 1 $\frac{1}{4}$ |
| 48 | 26 | 2 $\frac{1}{4}$ | 1.48 | 2 $\frac{1}{4}$ | 1 $\frac{1}{4}$ |
| 54 | 28 | 3 | 1.63 | 3 | 1 $\frac{1}{4}$ |
| 60 | 30 | 3 $\frac{1}{8}$ | 1.89 | 3 $\frac{1}{8}$ | 1 |
| 66 | 34 | 3 $\frac{1}{8}$ | 2.00 | 3 $\frac{1}{8}$ | 1 $\frac{1}{2}$ |
| 72 | 36 | 3 $\frac{1}{8}$ | 2.375 | 3 $\frac{1}{8}$ | 1 $\frac{1}{2}$ |

* Includes rubber, if rubber extends over flange face.

† Reference ASA B16.1, 125-psi cast-iron flanges.

‡ Reference ASA A21.2, Class 150 cast-iron pit-cast pipe.

§ Reference AWWA C207, Class E steel hub flanges.

|| Sizes up to 24 in.—reference ASA B16e6, 150-psi steel pipe.

Class 50-8 and 50-16 valves, as specified in Table 3; and for Class 125-8 and 125-16 valves, as specified in Table 4.

5.3. Unless otherwise specifically requested by the purchaser, bodies of all valves shall be of either cast iron (ASTM A126), cast steel (ASTM A27), or fabricated steel (ASTM A7).

6.2. All valve shafts shall have a minimum diameter extending through the valve bearings and into the valve disc, as specified in Table 5. If of "stub shaft" construction, each stub shaft shall be inserted into the valve disc hubs for a distance of at least 1 $\frac{1}{2}$ shaft diameters.

6.3. The valve shaft shall be securely attached to the valve disc by

means of keys, dowel pins, taper pins, or any combination of the three. The connection between the shaft and disc shall be designed to transmit shaft torque equivalent to at least 75 per cent of the torsional strength of the shafts listed in Table 5. Dowel and taper pins shall be mechanically secured.

6.4. Valve shafts shall be full size for the portion of the shaft that extends through the valve bearings, valve disc, and valve stuffing box and pack-

equivalent to at least 75 per cent of the torsional strength of the shafts listed in Table 5.

6.5. All valve shafts shall be of 18-8 stainless steel, Type 302, 304, or 316. Any deviation from these materials shall be only at the specific request of the purchaser.

Sec. 7—Valve Discs

7.1. Valve discs shall be of a cast or fabricated design, with no external

TABLE 5
Minimum Shaft Diameters*

| Valve Diameter in. | Shaft Diameter—in. | | | | | |
|--------------------------|--------------------|----------------|----------------|----------------|----------------|-----------------|
| | Class 25-8 | Class 25-16 | Class 50-8 | Class 50-16 | Class 125-8 | Class 125-16 |
| 3 | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ |
| 4 | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ |
| 6 | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ |
| 8 | $\frac{7}{32}$ | $\frac{7}{32}$ | $\frac{7}{32}$ | $\frac{7}{32}$ | $\frac{7}{32}$ | $\frac{7}{32}$ |
| 10 | 1 | 1 | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ |
| 12 | $1\frac{1}{8}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ |
| 14 | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ |
| 16 | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | 2 | 2 |
| 18 | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ |
| 20 | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{4}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ |
| 24 | $1\frac{1}{4}$ | $2\frac{1}{2}$ | 2 | $2\frac{1}{2}$ | $2\frac{1}{2}$ | 3 |
| 30 | 2 | $2\frac{1}{2}$ | $2\frac{1}{2}$ | 3 | $3\frac{1}{2}$ | $3\frac{1}{2}$ |
| 36 | $2\frac{1}{2}$ | $3\frac{1}{2}$ | 3 | $3\frac{1}{2}$ | 4 | $4\frac{1}{2}$ |
| 42 | $2\frac{1}{2}$ | $3\frac{1}{2}$ | $3\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | 5 |
| 48 | $3\frac{1}{4}$ | $4\frac{1}{4}$ | $3\frac{7}{8}$ | $4\frac{1}{8}$ | $5\frac{1}{8}$ | $5\frac{1}{8}$ |
| 54 | $3\frac{1}{2}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | 6 $\frac{1}{2}$ |
| 60 | 4 | $5\frac{1}{2}$ | $4\frac{1}{2}$ | 6 | $6\frac{1}{2}$ | $7\frac{1}{2}$ |
| 66 | $4\frac{1}{2}$ | 6 | 5 | $6\frac{1}{2}$ | 7 | $7\frac{1}{2}$ |
| 72 | $4\frac{1}{2}$ | $6\frac{1}{2}$ | $5\frac{1}{2}$ | $7\frac{1}{2}$ | $7\frac{1}{2}$ | $8\frac{1}{2}$ |

* Based on the use of 18-8 stainless steel, Type 302, 304, or 316.

ing gland. In the event that the valve shaft is turned down to fit connections to the valve operating mechanism, the turned down portion shall have ample fillets to eliminate the possibility of stress concentration at the junction of the two different shaft diameters. The turned-down portion of the shaft shall be capable of transmitting torque

ribs. The design shall be such as to sustain full differential pressures across a closed valve disc without exceeding a working stress of one-fifth of the tensile stress of the material used. The thickness through the center hub section of the valve disc shall be $1\frac{1}{2}$ – $2\frac{1}{2}$ times the shaft diameter listed in Table 5.

7.2. Valve discs shall be of cast iron (conforming to ASTM A48, Class 40); of cast steel (conforming to ASTM A27); of fabricated steel (conforming to ASTM A7), with non-corrosive seating edges of 18-8 stainless steel or Monel; or of cast bronze (conforming to ASTM B132).

7.3. Cast-iron or cast-steel discs shall have stainless steel or Monel seating edges; or, if requested by the purchaser, discs 20 in. in diameter or less may be provided with smooth, polished edges covered with a minimum

TABLE 6
Minimum Rubber Seat Thickness for
90-deg Seating Valves

| Valve Size in. | Min. Seat Thickness— <i>in.</i> | | |
|----------------------|---------------------------------|-----------------------|-------------------------|
| | Class 25-8 & 25-16 | Class 50-8 & 50-16 | Class 125-8 & 125-16 |
| 3-4 | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{1}{4}$ |
| 6 | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ |
| 8 | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ |
| 10-20 | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{3}{4}$ |
| 24 | $\frac{3}{4}$ | $\frac{3}{4}$ | 1 |
| 30-36 | 1 | 1 | 1 |
| 42-48 | 1 | 1 | $1\frac{1}{4}$ |
| 54-72 | 1 | $1\frac{1}{4}$ | $1\frac{1}{4}$ |

of 0.003 in. of chromium plating extending over the disc for a distance of at least 1 in. from the outside circumference.

Sec. 8—Valve Seats

8.1. Valve seats shall be designed to provide tight shutoff at the following pressure differentials:

Class 25-8 and 25-16: 25 psi upstream, 0 psi downstream

Class 50-8 and 50-16: 50 psi upstream, 0 psi downstream

Class 125-8 and 125-16: 125 psi upstream, 0 psi downstream.

8.2. Valve seats shall be of a design that permits removal and replacement at the site of the installation.

8.3. Valves with discs that seat at a 90-deg angle or at an acute angle to the pipe axis are acceptable; both types, however, shall be provided with adjustable mechanical stops to prevent overtravel of the valve disc in the open and closed position. The mechanical stops shall be designed to absorb the full operator torques listed in Table 8 (see page 952), with a minimum design safety factor of five.

8.4. For 90-deg seating valves, the minimum thickness at the seating surface shall be as specified in Table 6.

TABLE 7
Minimum Rubber Seat Thickness for
Acute-Angle Seating Valves

| Valve Size in. | Min. Seat Thickness in. |
|-------------------|----------------------------|
| 3-10 | $\frac{3}{16}$ |
| 12-20 | $\frac{3}{8}$ |
| 24-48 | $\frac{3}{4}$ |
| 54-72 | $\frac{3}{8}$ |

For valves that seat at an acute angle (not exceeding 81 deg), the portion of the seat that extends over the face of the body flanges shall be $\frac{1}{2}$ in. thick, and the minimum thickness at the seating surface shall be as specified in Table 7.

8.5. Valve seats shall be of pure gum rubber and shall be either: (a) cemented and clamped into the valve body; or (b) cemented or vulcanized into the valve body. If of Type (b), the rubber seat shall extend out over the face of each body flange.

Sec. 9—Valve Bearings

9.1. Valves shall be fitted with sleeve type bearings contained in the

hubs of the valve body. The maximum distance from the inside metal surface of the valve body to the inside end of the sleeve bearing shall not exceed $\frac{1}{8}$ in. Bearings shall be designed for a maximum bearing pressure of 2,500 psi.

9.2. If a shaft is designed for connection to an operator, a bearing shall be provided beyond the stuffing box gland. The housing for this bearing shall be rigidly attached to the valve body. If the operator is furnished as part of the valve assembly, the bearing may be fitted into the valve operator housing, which, in turn, shall be rigidly attached to the valve body.

9.3. Each valve shall be equipped with either one or two thrust bearings set to hold the valve disc securely in the center of the valve seat.

9.4. Sleeve and other bearings fitted into the valve body proper shall be of "self-lubricated" materials which do not have a harmful effect on water and which do not have a coefficient of friction in excess of 0.25 when run at the specified maximum bearing pressure on stainless-steel shafting having a finish equivalent to that used on the valve shafting. The bearing beyond the stuffing box gland may be of "self-lubricated" material of the "ball" or "roller" type.

Sec. 10—Stuffing Boxes

10.1. Where shafts project through the valve bodies for operator connection, stuffing boxes shall be provided. The design of the valve and stuffing box assembly shall be such that the packing can be adjusted or completely replaced without disturbing any part of the valve or operator assembly except the packing gland follower. Stuffing boxes shall have a depth not

less than the diameter of the valve shaft.

10.2. Stuffing boxes shall be made of cast iron (ASTM A126) or cast steel (ASTM A27). Gland assemblies shall be of cast bronze (ASTM B132). Unless otherwise specified by the purchaser, stuffing box packing shall be made of asbestos conforming to US Navy Dept. Specifications 33-P-26-b, Type A; or of flax packing conforming to Federal Specifications AH-P-106c.

Sec. 11—Operators

11.1. Valves shall have operators capable of transmitting sufficient torque to the valve shafts to seat and unseat the valve under the full design shutoff pressures and water velocities as specified for each class of valve. Minimum operator torques for valves shall be as specified in Table 8, and the torque shall not exceed 175 per cent of the minimum values listed in Table 8, up to 100 ft-lb; 130 per cent, from 100 to 1,000 ft-lb; 115 per cent from 1,000 to 10,000 ft-lb; and 110 per cent, above 10,000 ft-lb. The valve shaft at the connection to the operator shall be capable of transmitting the maximum operator torque without exceeding a torsional shear stress of 11,500 psi.

Sec. 11.2—Gearing

11.2.1. Operators that are composed of worm gearing shall be totally enclosed in a gear case and shall have worm gears of bronze and worms of hardened steel which operate in a lubricated bath.

11.2.2. Operators of the spur and rack type of gearing shall have gears and racks of at least 40 points carbon content and shall have hardened surfaces of at least 250 Brinell hardness.

Gears and racks shall be totally enclosed and provided with a means of lubrication.

11.2.3. Operators of the traveling-screw type shall have threaded reach rods of cold-rolled steel and shall have a bronze nut with internal threads.

Sec. 11.3—Manual Operators

11.3.1. Valves purchased with "manual" operators shall be furnished with

Sec. 11.4—Electric Operators

11.4.1. In electric operators, motors shall be capable of producing the torque specified in Table 8 at the required time cycle of valve operation. Unless otherwise specified by the purchaser, the operating time shall be 60 sec from the full-open to the full-closed position, or vice versa.

11.4.2. Electric motor drives shall be equipped with one pair of limit

TABLE 8
Minimum Operator Torque

| Valve Diameter in. | Min. Torque—lb-in | | | | | |
|--------------------------|-------------------|-------------|------------|-------------|-------------|--------------|
| | Class 25-8 | Class 25-16 | Class 50-8 | Class 50-16 | Class 125-8 | Class 125-16 |
| 3 | 8 | 8 | 12 | 12 | 19 | 19 |
| 4 | 14 | 14 | 22 | 22 | 36 | 36 |
| 6 | 33 | 33 | 52 | 52 | 93 | 93 |
| 8 | 61 | 63 | 95 | 95 | 175 | 175 |
| 10 | 98 | 115 | 160 | 165 | 320 | 320 |
| 12 | 146 | 200 | 240 | 280 | 510 | 510 |
| 14 | 205 | 310 | 340 | 450 | 720 | 720 |
| 16 | 275 | 470 | 470 | 670 | 1,030 | 1,030 |
| 18 | 360 | 660 | 600 | 940 | 1,350 | 1,480 |
| 20 | 445 | 920 | 770 | 1,300 | 1,800 | 2,050 |
| 24 | 680 | 1,550 | 1,200 | 2,200 | 2,900 | 3,500 |
| 30 | 1,250 | 3,100 | 2,100 | 4,350 | 5,300 | 6,750 |
| 36 | 2,150 | 4,500 | 3,400 | 7,550 | 8,500 | 11,600 |
| 42 | 3,400 | 8,450 | 5,350 | 12,000 | 12,800 | 18,400 |
| 48 | 5,050 | 12,700 | 8,000 | 18,000 | 18,500 | 27,500 |
| 54 | 7,250 | 17,000 | 12,000 | 25,500 | 29,500 | 40,000 |
| 60 | 9,900 | 24,800 | 16,100 | 35,000 | 38,500 | 54,000 |
| 66 | 13,300 | 33,000 | 21,400 | 46,000 | 49,500 | 71,000 |
| 72 | 17,000 | 42,500 | 27,000 | 60,000 | 60,500 | 90,000 |

operators that require a maximum input force on a handwheel or chain-wheel of not more than 40-lb pull to develop the operator torques listed in Table 8.

11.3.2. Manual operators shall be provided with a suitable mounting for future electric operators.

11.3.3. Manual operators shall be furnished with a device to hold the valve in a fixed position for an extended period of time.

switches and one pair of torque switches.

11.4.3. Any gearing in direct association with the electric motor drive shall be totally enclosed and shall operate in a lubricated bath.

Sec. 11.5—Hydraulic Cylinders

Unless otherwise specified by the purchaser, hydraulic cylinders shall comply with the following specifications:

11.5.1. Hydraulic (water) cylinders shall be of a size capable of delivering to the valve shaft the torque specified in Table 8.

11.5.2. Cylinder bodies shall be of hard drawn brass, with the inside diameter honed to at least a 15-RMS [root-mean-square] finish.

11.5.3. Cylinder pistons shall be of steel, with chrome plating on the portions of the piston that come in contact with the inside surface of the brass tubing and with cadmium plating on the portions in contact with water.

11.5.4. Cylinder head and cap ends shall be of solid steel, with cadmium-plated surfaces on the portions exposed to water pressure.

11.5.5. Cylinder piston rods shall be of stainless steel having a 5-10-RMS finish, with a surface of hard chrome plating of approximately 0.0005-in. thickness.

11.5.6. Piston rod bushings shall be of bronze and shall be pilot fitted into the cylinder head.

11.5.7. Cylinders shall be equipped with a dirt wiper to clean the piston rod before it enters the cylinder.

11.5.8. Cylinders shall be equipped with rod seals of a nonadjustable, wear-compensating type.

11.5.9. Rod seals and piston cups shall be of "Hycar" * rubber or equal.

11.5.10. Cylinders shall require not more than the pressure listed in Table 9 to be cycled a complete stroke in either direction before they are connected to the butterfly valve.

Sec. 12—Testing

12.1. *Performance tests.* After completion, each valve shall be shop operated twenty times from the fully closed

to the fully opened position, and vice versa, under a no-flow condition, to demonstrate that the assembly is workable.

12.2. *Leakage tests.* Each valve shall be shop tested for leaks in the closed position under full operating pressure differential. This test shall be conducted with the body flanges in a horizontal plane. With the disc in the closed position, air pressure shall be supplied to the lower face of the disc for the full test duration, as follows:

Class 25-8 and 25-16: 25 psi

Class 50-8 and 50-16: 50 psi

Class 125-8 and 125-16: 125 psi.

The upper surface of the valve disc shall be visible and shall be covered with a pool of water at 0-psi pressure.

TABLE 9
Pressure to Move Cylinder

| Cylinder Bore in. | Pressure psig |
|----------------------|------------------|
| 2 or less | 5 |
| 2+ through 5 | 4 |
| More than 5 | 3 |

The length of test shall be at least 5 min, and there shall be no indication of leakage past the valve disc (visible in the form of bubbles in the water pool on top of the disc) during the test period.

12.3. *Hydrostatic test.* With the valve disc in a slightly open position, internal hydrostatic pressure equivalent to the values tabulated below shall be applied to the inside of the valve body:

Class 25-8 and 25-16: 50 psi

Class 50-8 and 50-16: 100 psi

Class 125-8 and 125-16: 250 psi.

Under the specified hydrostatic test, there shall be no leakage through the

* A trade name of B. F. Goodrich Chemical Co., Cleveland, Ohio.

metal, the flanged joints, or the valve packing gland, nor shall any part be permanently deformed.

Sec. 13—Workmanship

The workmanship in the fabrication and assembly of valves covered by these specifications shall be first class in every respect. Valve parts shall be designed, and manufacturing tolerances set, to provide interchangeability in the products of any one manufacturer between units of the same size and type. When assembled, valves manufactured in accordance with these specifications shall be well fitted, smooth running, and watertight. All equipment shall be guaranteed against defects in workmanship or materials for one year after shipment has been made.

Sec. 14—Marking

Markings shall be cast on the body of cast valves and stamped on the flange rim of fabricated valves to show the valve size, class, and year of manufacture.

Sec. 15—Painting

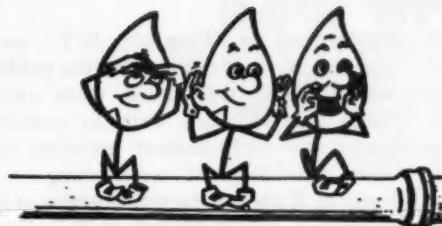
Unless otherwise specified by the purchaser, an asphalt varnish made to comply with Federal Specifications TT-V-51a, or US Army and Navy

Specifications JAN-P-450, shall be applied to the ferrous part of the valves, except to finished or bearing surfaces. Surfaces shall be clean, dry, and free from grease before painting. Two coats each shall be applied to the inside and outside ferrous metal.

Sec. 16—Inspection and Rejection

16.1. All work done under these specifications shall be subject to inspection and approval by the purchaser's duly authorized engineer or inspector, who shall at all times have access to all places where materials are being produced or fabricated or where tests are being conducted, and who shall be accorded full facilities for inspection and observation of tests. Any butterfly valve or part which the inspector may condemn as not conforming to the requirements of these specifications shall be made satisfactory or shall be rejected and replaced.

16.2. If the purchaser has no inspector at the plant, the manufacturer shall, if requested at the time the order is placed, certify that the required tests on the various materials and on the completed valves will be made, and that no component or valve shall be furnished which has not been tested and found to conform to the requirements of these specifications.



Percolation and Runoff

So watery has been the nation's eye of late that it's little wonder our inventive geniuses have begun to blink a bit in our direction. Not large-scale looks such as our rainmakers and sea-water fresheners have so long and so seriously been casting, but the more exciting glances of the gadgeteers, who discover ways of saving a few gallons for a few dollars, while the problem of increasing supply is being more laboriously solved. Just last month, for instance, three devices to save watering water were announced:

• The *Irrigate*, which measures the moisture content of the soil and, thus, permits the farmer, the greenskeeper, or the cemeterian to save the water he normally loses by overirrigation—said to amount to as much as 60 per cent of the total used. Measurement is made through a series of 2-ft gypsum stakes buried in the ground at key spots in field or fairway and hooked up to a special resistometer, provided with a selector that makes possible readings at any of the four depths—6, 12, 18, and 24 in.—at which the stakes absorb moisture from the soil. The stakes are low, at \$12.50 each, but the meter costs \$189.50. Still, Rayturn Corp. of Portland, Ore., which manufactures the gadget, claims that in saving water and

labor to the tune of \$1 to \$5 per acre per year, the *Irrigate* can pay for itself in a single growing season.

• An *automatic gardener*, which controls the operation of underground sprinkling systems, relieving the home gardener or lawnderer not only of the chore of turning the water on and off, but even of remembering whether or not it has rained recently enough or hard enough to make sprinkling unnecessary. Designed to be hung on a wall in the basement or garage and to be plugged into a regular a-c outlet, the device works somewhat like an automatic oven, turning the water on and off at the times set on its two dials. One setting keeps the controller operating on the same cycle daily, interrupted only when a signal from an outside moisture-measuring device indicates that sprinkling is not needed, by tripping the switch to "off" for another 24-hour period. Made by the Tork Clock Co. of Mount Vernon, N.Y., papa's little helper is said to save its \$80 price quickly in water conserved as well as in fees to sprinkler sitters during vacations and other absences.

• An *automatic water warden*, which cuts off sprinkling and other outside water use when system pressure falls

(Continued on page 34 P&R)

(Continued from page 33 P&R)

to a predetermined "critical" level, and then restores service when the pressure returns to normal. Operated by a simple, snap-action valve, this device is designed primarily for installation on the sillcock, where it effects a positive and automatic sprinkling ban that is enforced only when actually necessary. The valve, which is actuated by a negative spring, permits pressure settings through a 100-psi range, with on-off differentials as small as 5 per cent if desired. One model, developed specifically for utility use, is designed to be wire-sealed in place. Cost of the unit, according to the manufacturer, is little more than that of a regular faucet, and test samples are available at that "cost" from Duroset Corp., 18512 Detroit Ave., Cleveland 7, Ohio. Not only in avoiding back-siphonage and in maintaining pressure at fire hydrants, but in public relations as well, such a gadget ought to be a handy one for the harassed water worker.

Not of the same class exactly, but certainly mothered by the same necessity, are such developments as the new waterless air conditioner introduced by General Electric Co. for home installations and the rash of new industrial equipment and processes which are designed to reduce water use to a minimum. Not only inventive genius, but just plain ingenuity has been at work, too, toward the same end. Out at Plainfield, N.J., for instance, where the fire siren substitutes for the pressure-sensitive valve, in calling a halt to lawn sprinkling when the pressure drop is too severe. Or at Haltom City, Tex., where Mayor Virgil Goodman ordered water service cut off entirely when residents defied the ordinance banning afternoon lawn sprink-

ling. And at Wantagh, N.Y., and Verona, N.J., where at least the public water supply was saved when residents dug backyard wells to provide water for such banned activities as lawn sprinkling and car washing.

As a matter of fact, about the only thing that hasn't been done so far to emphasize the value of water is the obvious one of fixing its price commensurate with its value. What price water then?

Annual reports of water utilities are needed to keep up the inventory of community water supplies being maintained in Washington for industrial mobilization purposes. All water utilities are urgently requested to add to their mailing list for annual reports the following address:

Water & Sewerage Industry & Utilities Div.
Business & Defense Services Admin.
Dept. of Commerce
Washington 25, D.C.

Thorndike Saville, dean of the New York Univ. College of Engineering, has been awarded the Lamme Medal of the American Society for Engineering Education for his work in teaching and the advancement of the engineering profession.

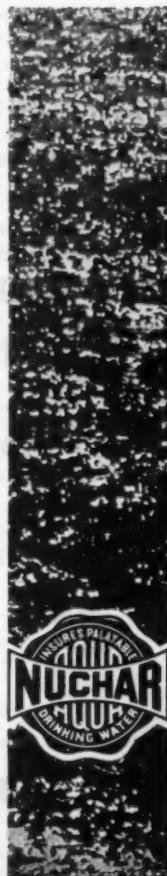
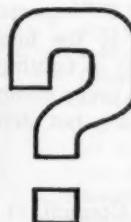
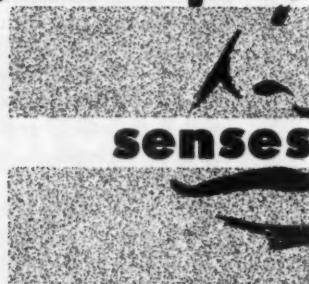
William T. Ingram has opened New York offices as a consultant in sanitary engineering. His home office is at 20 Point Crescent, Whitestone 57, N.Y.; his laboratory at 148 Islip Ave., Islip, L.I., c/o South Shore Labs. He continues his connection with the College of Engineering of New York Univ. as adjunct professor and project director for sanitary engineering and related research.

(Continued on page 36 P&R)

how are your



organoleptic



• Many consumers have very *keen* organoleptic senses. The disagreeable tastes and odors that come to water suddenly, and without warning, sometimes cause the most irritating complaints. Threshold Odor Tests, thus, ought to be conducted frequently to determine what dosages of AQUA NUCCHAR—activated carbon—are required to assure a palatable supply. Technicians from INDUSTRIAL, as part of their regular service and *without obligating you*, will run an odor survey of your plant and determine how AQUA NUCCHAR may be applied most efficiently. They will also instruct you in the techniques of making the odor tests yourself, and advise how AQUA NUCCHAR—activated carbon—may be best used with other chemicals in your process.

AQUA NUCCHAR is the long-proven, accepted product for use in achieving water that is satisfyingly palatable. Many operators are extremely enthusiastic not only about the way AQUA NUCCHAR—activated carbon—improves odor and flavor but also about the manner in which it imparts a pleasing cut-diamond appearance to water.

Contact INDUSTRIAL, now!

industrial
CHEMICAL SALES
division west virginia pulp and paper company



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230 Park Ave. Broad & Chestnut 35 E. Wacker Dr. Blvd.
New York 17, N. Y. Philadelphia 7, Pa. Chicago 1, Ill. Cleveland 20, Ohio

(Continued from page 34 P&R)

There are four born every minute—and only the ten million gallons of water produced in that same time by our public water suppliers prevents them from eating us out of house and home. Fires, we mean, of course, and with Fire Prevention Week coming along early next month—October 3-9—perhaps you and the fire chief can work out some stunt that will call attention not only to the importance of fire prevention but to the important job that you both do in fighting fires. There are four born every minute, but we're the suckers for not drowning their stork.

Engineers Joint Council, in an attempt to increase its services to the engineering profession, has recently

taken two actions of importance. In the first, EJC plans the organization of a joint engineering agency to deal with the problems of nuclear engineering. In the second, EJC continues the trend toward liberalization of its membership policy (which recently resulted in the admission of AWWA and several other organizations) by adopting two new constitutional amendments. The amendments extend eligibility for EJC membership in various grades to small, regional, and other types of societies.

John C. Finn has been appointed New England sales agent for US Pipe & Foundry Co. He will work through the company's Boston office, with which he has been associated since 1937.

(Continued on page 38 P&R)

AMONG WATER WORKS MEN

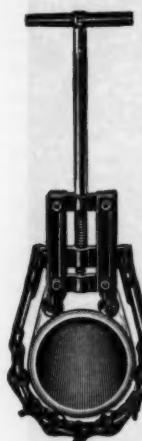
THE HEAVY-DUTY ELLIS PIPE CUTTER is *BEST*

FOR CUTTING LARGE
SIZES OF PIPE

No. 01 Cuts Pipe 4" to 8"
No. 1 Cuts Pipe 4" to 12"

Write for circular and price list
No. 35J, on our complete line of
pipe cutting tools.

ELLIS & FORD MFG. CO.
2425 Goodrich Ave. Ferndale, Michigan
Phone Lincoln 2-5620



Glazed Fire Clay

Tile Filter Bottoms

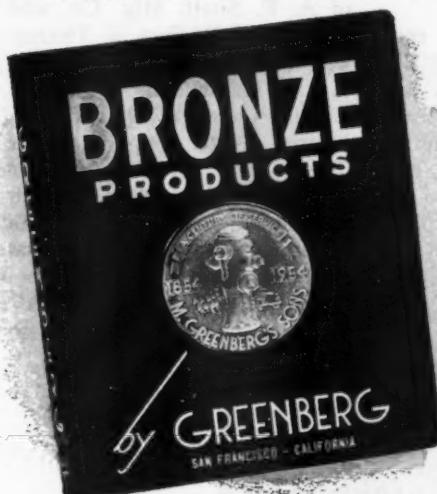
Successfully serving over 250 plants
with a daily capacity of more than
1½ billion gallons.

Permanent • No corrosion or
tuberculation • Equal distribution •
Uniform filtration • Low loss of
head • Requires only small sized
gravel • No metal in contact with
water!

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Manufacturers of: Underwriters Approved fire hydrants, hose valves and siamese connections. Fire protection hose goods; industrial, Navy and maritime bronze valves and fittings; plumbing and hardware brass specialties; bronze plaques, letters and name plates; crematory and cemetery bronze products.

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If additional copies are desired, please list name and title of person to receive catalog.

(Continued from page 36 P&R)

Wellington Donaldson, deputy director of the Div. of Sewage Disposal, New York City, has retired after 20 years of service with the city. Before coming to New York he had a brilliant career as a chemist, a works engineer, and a consultant.

Dollar Bill was the sobriquet conferred upon AWWA Treasurer Bill Brush at his 80th birthday party last July 28th, when a group of his friends and associates of the past 60 years in water works and words wished him many, many more happy returns of the day. Among those present at the luncheon, hosted by AWWA Finance Committee Chairman Bill Orchard, were Ed Clark, who succeeded Brush as chief engineer of the New York

City Department of Water Supply, Gas, and Electricity, when he retired from that job some 20 years ago, and Karl R. Kennison, now with the city's Board of Water Supply; consulting engineers Charlie Emerson and Dick Hazen; manufacturers Hubert O'Brien of A. P. Smith Mfg. Co., and Tom Quigley of Wallace & Tiernan; and water works executives Charlie Alfke of the Hackensack Water Co. and Charlie Capen of the North Jersey District Water Supply Commission. These, their wives, and members of AWWA's headquarters staff felicitated the neophyte octogenarian not only on his attainment of that august state, but on his long career of service to the public, to the industry, and to AWWA, which he has served for 30 years as

(Continued on page 40 P&R)

Having **turbidity** problem?

Clear it with N® Activated Silica

Water treated by a N-Sol silica aid and alum or ferric salts sparkles like spring water. (Turbidity often reduced to as low as 1.0 to 0.5 ppm).

Activated silica sol is prepared in your plant from N® Sodium Silicate and a reacting chemical. N-Sol patented processes for preparing activated silica sols are licensed without royalty.

Let us send you without obligation complete information on the N-Sol Processes for coagulating raw or waste waters.

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PQ® SOLUBLE SILICATES

WORTHINGTON-GAMON**WATCH DOG**

The meter used by thousands of municipalities in the U. S.

**WATER METERS**

"Watch Dog" models . . . made in standard capacities from 20 g.p.m. up: frost-proof and split case in household sizes. Disc, turbine, or compound type.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE.

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch



Dog Water Meters first choice of so many municipalities and private water companies in the United States.

WORTHINGTON-GAMON
METER DIVISION

Worthington Corporation

296 SOUTH STREET, NEWARK 5, NEW JERSEY



OFFICES IN ALL PRINCIPAL CITIES

(Continued from page 38 P&R)

treasurer and for many more in other offices and capacities. An inscribed silver tray was presented to him as a memento of the occasion, and members of the Association staff sought to guarantee his continued ability to sign their checks with a pen set, a reserve supply of ink, and these sentiments:

Not just eighty years of livin'
But the thirty that he's given
To the keeping of our till
Bids us honor "Dollar Bill"
With a gift, not to amuse
But use . . . and use . . . and use!

For crying out loud! One weekend of rainfall at Weeping Water, Neb., this year totaled 4.19 in. A lost weekend, too, with nary an AWWA member in town to benefit by it.

In the fancy, a young man's springs—but it wasn't always that way. As a matter of fact, when the man—Roland Wood of Grand View, N.Y.—moved into his present home, the first of the springs was all too agonizingly extant, in the basement, where it had been at work long enough to undermine the foundation. So before he moved in, Wood had to jack his house up and put a new foundation under it. But being a brook lover, he was more happy than not over the find, and diverted the stream to the front of the house where he had a professional landscape architect pretty it up with bridges, stepping stones, and all the other accouterments of a domesticated spring. No sooner had this been accomplished than another spring ap-

(Continued on page 42 P&R)

WHY USE JOHNSON WELL SCREENS?

1. **Less drawdown.**
2. **Greater specific capacity.**
3. **Lowest pumping cost per million gallons of water.**

True economy is measured not by first cost alone, but in lowest yearly cost. The JOHNSON WELL SCREEN combines an unmatched record of experience and dependability with greatest strength and durability. It is the finest and most truly economical well screen in the world.

EDWARD E. JOHNSON, INC.

~ well screen specialists since 1904 ~

St. Paul 14, Minn.





how much does it cost... **to "crank" an old chlorinator?**

The automobile self-type starter isn't news any more — nobody ever cranks a car these days. Cranking" an old-style chlorinator is equally out-dated.

The F&P mechanical, instrument-type chlorinator is sweeping the country, sales mount month by month. Why? Because municipality after municipality, consulting engineer after consulting engineer, reports the same facts: F&P chlorinators are lower in first cost, are easier to handle, because they are so simple in design, so light in weight, so modern in construction. More important, however, it is always stressed that F&P chlorinators require practically no maintenance, practically no spare parts.

We claim that if you are operating a chlorinator that has a bell jar on it you *need a new chlorinator*. You are "cranking" an old, costly, inefficient chlorinator. Everybody knows that chlorine is not corrosive—but that as soon as you put the chlorine in contact with water or

water vapor it becomes corrosive. That's what the water tray types of chlorinators do—put dry, non-corrosive chlorine in contact with water and make corrosive vapor out of it. It's not engineering sense and the way to avoid it—and the resulting expensive maintenance—is to get F&P *mechanical, instrument type* chlorinators.

Don't refrain from writing us because you don't need additional chlorinating capacity right now. Moreover—if it is time for a major overhaul or a rebuilding of your bell jar chlorinator, let us quote you for doing this work. We will give you what you may not have gotten previously—a firm price for doing the job before we start on it. The price will be a reasonable one, but we'll also quote you a price for replacing the chlorinator and if you want to spread the cost of the new one by time payments or if you want a lease arrangement, you can have it. Chances are you cannot justify further overhaul or further rebuilding—even at our *fair* price for doing the work.



complete process instrumentation
FISCHER & PORTER CO.
994 Fischer Road, Hatboro, Penna.

YRS. EXPERIENCE SUCCESSFULLY MANUFACTURING CHLORINE FLOW METERING EQUIPMENT

(Continued from page 38 P&R)

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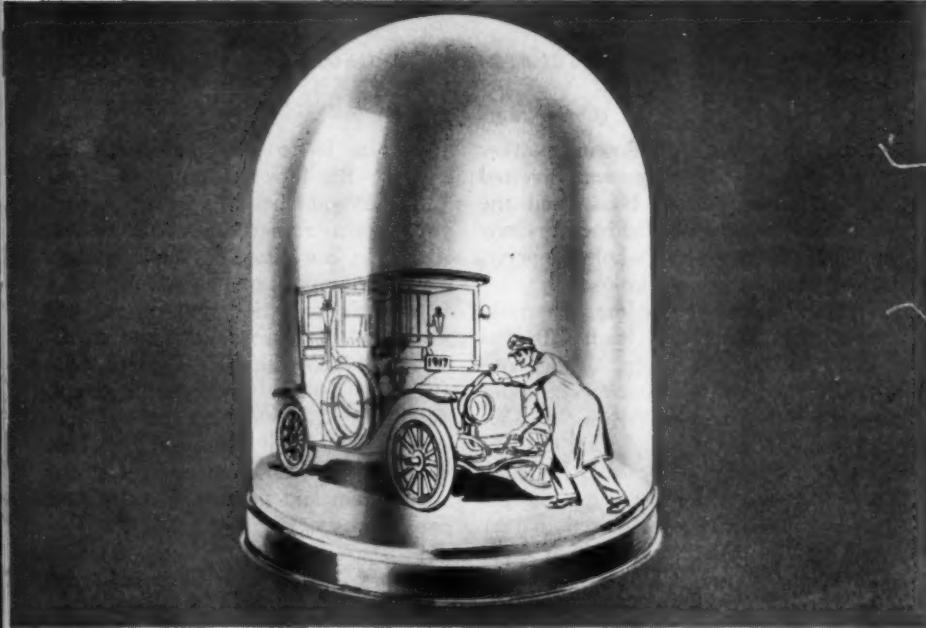
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2. **Greater specific capacity.**
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True economy is measured not by first cost alone, but in lowest yearly cost. The JOHNSON WELL SCREEN combines an unmatched record of experience and dependability with greatest strength and durability. It is the finest and most truly economical well screen in the world.

EDWARD E. JOHNSON, INC.
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T.M., F&P CO.

complete process instrumentation
FISCHER & PORTER CO.
994 Fischer Road, Hatboro, Penna.

YRS. EXPERIENCE SUCCESSFULLY MANUFACTURING CHLORINE FLOW METERING EQUIPMENT

(Continued from page 40 P&R)

peared out of the lawn, flowing another 9 or 10 gpm. That one was diverted to the other side of house and the landscape architect called back to draw up new plans for the whole property, to emphasize the two brooks.

Plans were proceeding famously when Mr. Wood left town. It was then that the Tappan Zee Bridge construction north of Two Brooks damaged a water main of the Spring Valley Water & Supply Co. That brought a repair crew into the area to patch up after the bridge builders, in the process of which they repaired another leak in the main on which they were working. Off went the crew, on went the Tappan Zee, and glug went the brooks. "It appears," said Supt. Charley Lipp, "that the streams came

from the 18 to 20-gpm leak in our pipes." But how is it going to appear to Mr. Wood when he gets back? One thing seems rather sure: with all that expensive concrete work and landscaping in full view, no one from the water company's collection department will cross one of those dry bridges to deliver a bill for the 10 mil gal or more per year required to keep the brooks supplied. We wouldn't be too surprised, though, if the master of Two Brooks didn't hook his brooks to the main again and turn them on at least for company.

George L. Curtis, formerly chief engineer of United Concrete Pipe Corp., Baldwin Park, Calif., has been made vice-president, engineering.

(Continued on page 46 P&R)



For Public Water Fluoridation

Sodium Silicofluoride—98%

(Dense Powder)

Sodium Fluoride—98%

(Dense Powder or Granular)

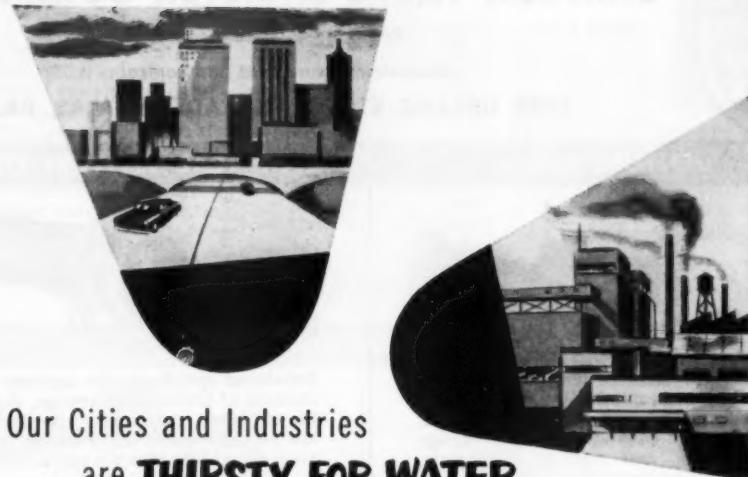
Meets AWWA specifications

White or tinted blue
Minimum of dust in handling
Minimum of storage space

Available in bags and drums

The AMERICAN AGRICULTURAL CHEMICAL CO.

50 Church Street, New York 7, N. Y.



Our Cities and Industries
are **THIRSTY FOR WATER**
.....so is Agriculture

As more and more people move into private homes, water consumption climbs sharply. Without exception new production techniques in industry result in increased need for water . . . on our farms and ranches, the rapid growth of irrigated acreage means that more water is needed so that our food production can keep pace with population growth. America is truly thirsty!

Layne—the world's largest developers of ground water resources—knows most about these thirsts and how to satisfy them.

The knowledge and experience gained the world over is at your service. Your nearest Layne Associate Company can answer any question that relates to water—or write direct.

LAYNE & BOWLER, INC.

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*Layne Associate Companies
Throughout the World*

Water Wells • Vertical Turbine Pumps • Water Treatment



SIMPLEX VALVE & METER COMPANY

Reliable equipment for

accurate measurement and control

6784 UPLAND STREET, PHILADELPHIA 42, PA.

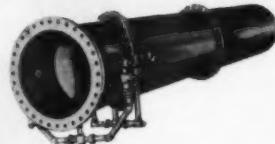
VENTURI TUBES



WRITE FOR
CATALOG 004

For accurate measurement of hot or cold water, gases, sewage, sludge or trade wastes under wide ranges of pressures. Flanged, bell, or spigot ends in any size or design . . . cast-iron, cast steel or steel plate, bronze, or combinations.

ELLIPTICAL VENTURI TUBES



WRITE FOR
BROCHURE

Developed specifically for accurate measurement of low velocity sewage, sludge or heavily laden trade wastes—flowing under low pressure conditions. Flat top prevents air binding! Flat invert is self-scouring!

PARABOLIC FLUMES



WRITE FOR
BULLETIN 800

Specially designed to measure sewage, sludge, and trade wastes under low heads or open flow. Can be used for indicating, or with meter to record and totalize. Simple to install. Full 20 to 1 flow range. Flanged, bell or spigot inlet in 6" to 36" standard pipe sizes.

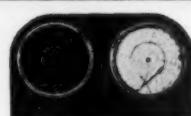
PITOT EQUIPMENT



WRITE FOR
BULLETIN 1300

Leaks and line breaks are quickly located with Simplex pitot rods, manometers and recorders. Light-weight, compact design makes them truly portable. Invaluable for overall survey of your distribution system's efficiency.

FILTER GAUGES



WRITE FOR
BULLETIN 1000

Indicate and/or record essential data on rate of flow, loss of head, sand expansion, water level, etc. Attractive units with easy to read dials. Floor stand mounting—or Operating Tables for convenient centralized control.

CONTROLLED CLOSING VALVE



WRITE FOR
BROCHURE

Prevents surge and water hammer damage when filling larger size pipe lines. Controls speed of line closure, vents air and, if necessary, discharges water to prevent damage. Admits air to protect against pipe collapse from line breaks.

SIMPLEX VALVE & METER COMPANY

SIMPLEX FLOW METERS



TYPE M0 METERS

Most accurate inferential type instrument for water, sewage, sludge, industrial liquors. Indicates, records, totalizes. Measures within $\pm 2\%$ over ranges up to 20 to 1. Easy-to-read, evenly-spaced rectangular chart. Wall, floor stand, or panel mountings.

WRITE FOR BULLETIN 500

REMOTE TRANSMISSION

PNEUMATIC — New Simplex Laminair® is fast and accurate. Permits centralizing instruments in main control panel away from primary devices.

ELECTRIC — New Simplex Orthoflow® transmits data over in-plant circuits and leased telephone channels. Accuracy within $\pm 2\%$ for ranges up to 20 to 1.

WRITE FOR BROCHURE



TYPE H METERS

Mercury-float type indicating, recording and totalizing unit. Gives $\pm 2\%$ accuracy at any point for flow ranges up to 13 to 1. Evenly spaced scales make accurate readings easy. Wall, panel, or floor stand mounting.

WRITE FOR BULLETIN 401

FLOW RATE CONTROLLERS



SLUDGE CONTROLLERS — Accurately control flow of sewage, sludge, trade wastes. Most accurate primary device, a Simplex Venturi Tube, has a special throat section of flexible rubber—measures as it controls! Motor-driven clamp adjusts throat... keeps flow at control point. Viscous flows contact no moving parts.

WRITE FOR BROCHURE



TYPE S FLOW CONTROLLERS

Keep flow constant despite changes in head of filter effluent or wash water. Control within $\pm 3\%$ over 5 to 1 range. Exclusive balanced guillotine valves quickly respond to slightest change. Standard sizes from 3" to 24".

WRITE FOR CATALOG 604

SIMPLEX AIR RELEASE & INLET VALVES



AIR RELEASE VALVES

Vent air accumulations to eliminate binding at high points, increase pumping efficiency. Simple, rugged 1" and 2" sizes for up to 250 psi. Special valves available for up to 800 psi.

WRITE FOR BULLETIN 1200



AIR INLET VALVES

Prevent collapse of thin-walled pipes from sudden pressure drops in gravity lines. Simple, reliable float control quickly admits air to break vacuum. Available in 4" to 10" sizes.

WRITE FOR BULLETIN 1202



COMBINATION INLET-RELEASE VALVE

One compact unit with a 2" connection does work of two separate valves! High discharge and inlet capacities. Invaluable for venting large quantities of air when filling systems.

WRITE FOR BULLETIN 1203

RELATED SIMPLEX® EQUIPMENT

- FLOW REGULATORS
- INSERT-TYPE VENTURI TUBES
- TAILOR-MADE MEASUREMENT & CONTROL EQUIPMENT
- LARGE DIAL GAUGES
- SPECIAL VALVES

SIMPLEX VALVE & METER COMPANY

(Continued from page 42 P&R)

E. N. Zimmerman, who has been assistant advertising manager of Chicago Bridge & Iron Co. since 1945, has been advanced to advertising manager. He has been with the firm in various capacities since 1937.

M. A. Mathews, Texas sales engineer for Neptune Meter Co., has returned to his office in Aransas Pass, Tex., after two years with the Marine Corps in Camp Lejeune, N.C., and Puerto Rico. He had come to Neptune in 1949 from the Houston, Tex., Water Dept., which he had served as chemist and assistant sanitary engineer. In 1952 he was recalled to active duty as a major with the Second Engineer Battalion of the Second Marine Div.

A. R. Whittaker, general manager of the Rockwell Mfg. Co. water meter division at Brooklyn, N.Y., has been named director of water meter research and development, with offices at company headquarters in Pittsburgh. He will be succeeded as general manager by Roy C. Kain, his assistant since 1947.

Wallace T. Miller has resigned as manager of the Rochester Div., New York Water Service Corp., in order to join the staff of the Cast Iron Pipe Research Assn. at Chicago.

A Houston sales office has been opened by Reilly Tar & Chemical Corp. at 2009 Fannin St., with Donald Becker in charge.

(Continued on page 48 P&R)



General Sales Offices
ANNISTON, ALABAMA

We invite inquiries to our nearest sales office

120 S. Michigan Ave.
Chicago, Illinois

350 Fifth Avenue
New York 1, New York

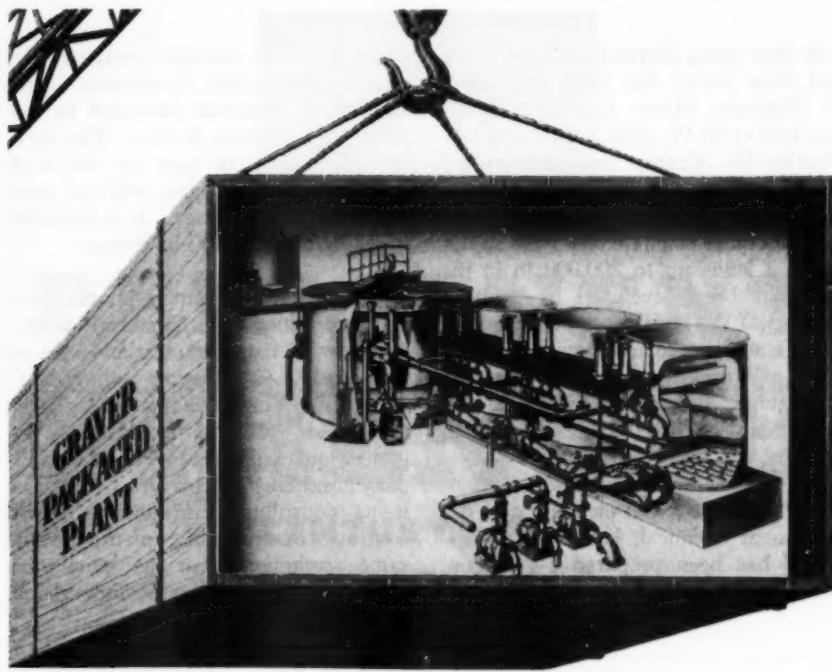


Each length of pipe we manufacture passes through the above hydrostatic test press where it is filled with water and the pressure raised to 500 pounds per square inch. The most common water works pipe is designed for an operating pressure of 130 pounds per square inch. This undergoes the 500 pounds per square inch hydrostatic test and permanent records for each piece of pipe are kept on file for inspection by our customers at all times. You can be assured with Alabama's Super De Lavaud Cast Iron Pipe. In sizes of 3" to 24" in modern long lengths. Bell and Spigot, Mechanical Joint and Flanged Pipe.

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You get more for your money with Graver's "packaged" plant for water treatment and filtration because there are these savings:

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2. **PRODUCTION**—Responsibility centralized in one dependable equipment supplier for maximum economy in fabrication, assembly and construction.
3. **OPERATION**—Designed with simplified controls and up-to-date materials of construction to minimize necessary operating attention.

A Graver "Packaged" Water Treatment Plant includes (ready for installation): High-rate, solids-contact coagulation and softening Reactivator® of either concrete or steel construction; gravity or pressure filters; clearwell, chlorinator, wet or dry chemical feeders, recarbonator where required, and controls. There is nothing more to buy.

Write for Graver Municipal Bulletin and Sample Layouts.



GRAVER WATER CONDITIONING CO.
A Division of Graver Tank & Mfg. Co., Inc.
215 West 14th Street, New York 11, N.Y.

(Continued from page 46 P&R)

A new sales district for New York and New Jersey has been established by Neptune Meter Co. with headquarters at 50 W. 50th St., New York. Charles W. Krause has been named branch manager.

A portable concrete tester for applying test loads up to 200,000 lb in the field has been developed by Soiltest, Inc., 4520 W. North Ave., Chicago 39, Ill. In addition to accommodating concrete cylinders 6 in. in diameter and 12 in. high, the instrument can be converted into a 20,000-lb flexure testing machine for beam tests.

A "package" well cleaning and development chemical, known as "Wel-tone," has been prepared by Calgon, Inc., to do a complete job of well

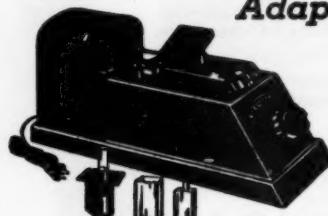
cleaning. The mixture contains Calgon, a disinfectant, a wetting agent, and other chemicals intended to improve the cleaning action. The mixture is said to be safe for use with concrete or metal, and will not generate dangerous fumes. It is available in 15-lb cans or 100-lb drums.

Bond-O sulfur joint compound, formerly produced by Northrop & Co., will now be manufactured and sold by the Bond-O Co., Spring Valley, N.Y. James F. White, who has long been associated with the predecessor organization, will head the new company; and Guy C. Northrop will serve it as consultant. Manufacture will continue in the same plant, by the same workmen, from the same minerals, and under the same supervision.

(Continued on page 50 P&R)

KLETT SUMMERSON ELECTRIC PHOTOMETER

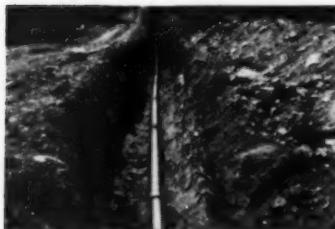
*Adaptable for Use in Water
Analysis*



Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

KLETT MANUFACTURING CO.

179 EAST 87th STREET . NEW YORK, N. Y.



"Century" Pipe installation, Brookwood Estates, Stanhope, N. J.

PERMANENT STRENGTH

"CENTURY" PIPE

as its name suggests, retains its great strength for generations. One reason is that the materials used to make it (asbestos fiber and portland cement) are themselves inherently strong and durable. Secondly, K&M maintains rigid quality control throughout the manufacturing process. To be certain of high strength and uniformity of construction, K&M tests every length, both hydrostatically and in flexure, before it leaves the plant. "Century" pipe has proved its strength by long service in many kinds of soil.

Consider the many other distinct advantages of "Century" pipe and you'll see why more and more thrifty towns are choosing it—why it's the wise choice for your community too!

Write for further information now.

QUALITIES THAT MAKE "CENTURY" PIPE ECONOMICAL, TROUBLE-FREE, LONG-LIVED

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|------------------------------|-------------------------|
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| 2. NON-CORROSIIVE | 7. SMOOTH BORE |
| 3. <u>PERMANENT STRENGTH</u> | 8. EASILY, QUICKLY LAID |
| 4. DURABLE | 9. LIGHT WEIGHT |
| 5. IMMUNE TO ELECTROLYSIS | 10. LOW COST |

"Century" pipe meets the A.W.W.A., A.S.T.M. and Federal Specifications for asbestos-cement pressure pipe.

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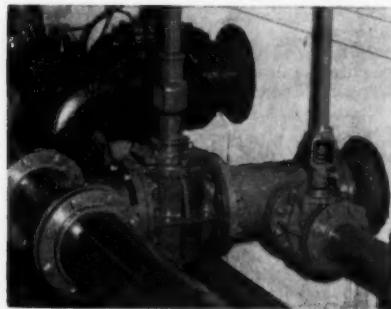


(Continued from page 48 P&R)

Dull and inconspicuous service is what the residents of High Point, N.C., want, and to get it 23 of them filed civil suits against the city totaling more than \$200,000. Source of the damage claimed was the brightness of the city's aluminum finish water storage tank. Settlement out of court cost the city \$2,500 in drab paint—a rather unsatisfactory way to spend public relations funds.

Its Mexican subsidiary is now manufacturing deep well turbine pumps in a plant near Mexico City recently acquired by Byron Jackson Co. The plant is intended to meet the needs, both now and in the future, of the country's agricultural, industrial, and domestic development.

A consent judgment signed by Wallace & Tiernan Inc. on July 26 ended an 8-yr-old antitrust action of the Dept. of Justice. A companion criminal case was also ended with the entry of *nolo contendere* pleas and the assessment of fines. In signing the judgment, the company observed that settlement appeared less burdensome than extended litigation, and that it was signed without admission by the parties on any of the issues, and without trial of fact or law. Affecting only the domestic chlorination business of the company, the judgment requires principally that W&T notify competitors when it furnishes engineering services in large prospective installations. The company's activities in trade associations are covered by other provisions.



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Every day, more and more DeZurik Valves are being installed in new plants or being specified to replace worn-out valves in existing plants. As intake, discharge and backwash valves on sand filter beds, DeZurik Valves insure tight shut off despite sand and silt in the flow and resist the abrasive action of suspended matter. Available in lever, gear or remotely operated models, and in sizes thru 20". Write for details.

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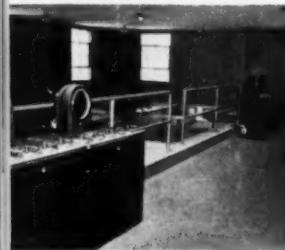


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Taylorville's 1500 gpm Permutit Precipitator softens and clarifies in *half* the time of a settling basin.



utit Filters and Operating Tables produce crystal-clear water. Monocrete® rdrain has cast-concrete headers and is to reduce costs.



Taylorville's New Water Softening Plant
Engineering: M & Van Praag, Inc., Decatur, Ill.
Contractor: Tillman Co., Inc., Centralia, Ill.

Since 1888, hardness of up to 974 ppm had wasted soap, left sticky curd on dishes and clothes, formed scale to clog pipes, wreck water heaters.

After World War II, geologists found one of the best well-field sites in central Illinois. Hardness was about 200 ppm, still far too high to satisfy taxpayers, far-sighted city officials.

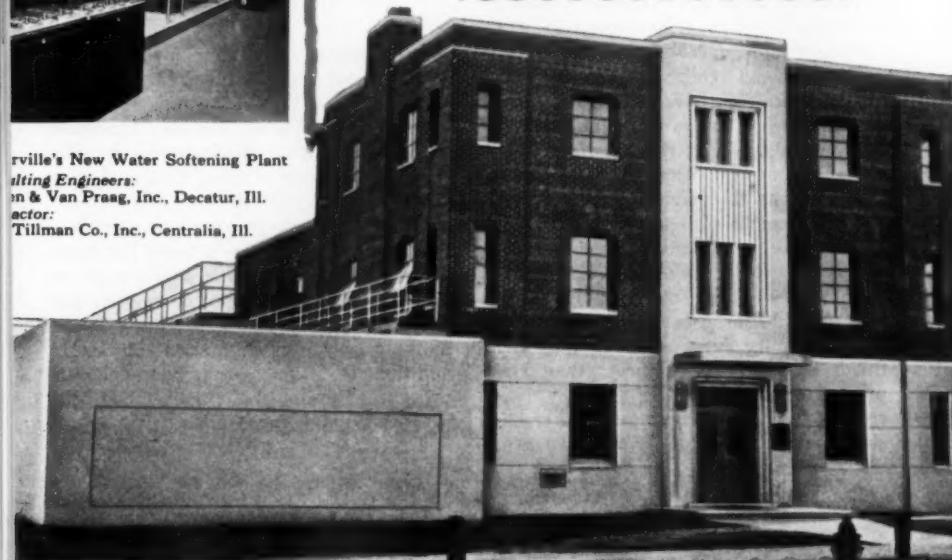
So when well-field contracts were awarded, the project included a modern water softening plant. Consulting engineers recommended Permutit equipment.

Taylorville's Precipitator (shown at left) reduces hardness, turbidity and alkalinity in a single, quick step. Its efficiency greatly reduces filter loads, cuts backwashing to a minimum.

This Permutit installation reduces hardness to the specified range of only 60-80 ppm (a mere 4 grains) . . . a far cry from Taylorville's old 974 ppm level!

Permutit equipment can bring similar benefits to *your* city. Write today for information. The Permutit Company, Dept. JA-9, 330 West 42nd St., New York 36, N. Y., or Permutit Company of Canada, Ltd., 6975 Jeanne Mance St., Montreal.

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The Reading Meter

Field Practice. *Elwyn E. Seelye.* Vol. 3 of "Data Book for Civil Engineers." *John Wiley & Sons, New York (2nd ed., 1954) 394 pp.; \$7.50*

From the voluminous format of the first two volumes of the *Data Book for Civil Engineers*, the slightness of the third and last volume has always seemed an appropriate departure, as its handy size permits it to be consulted on field practice in the field. Much of the material is directed toward helping inspectors check on the progress of construction work. There is also some coverage of administrative detail, sources of job power, much on surveying, and soil mechanics. In its second edition, *Field Practice* continues to be a useful volume in a valuable reference series.

Public Water-Supply Shortages, 1953. *K. A. MacKichan & J. B. Graham. Supplement 3, Water Resources Review. Geological Survey, Washington 25, D.C. (1954) 8 pp.; paperbound; free*

Prepared in collaboration with the Water Resources Div. of Canada's Dept. of Northern Affairs & National Resources, this booklet records the statistical occurrence of water supply shortages, as defined by the affected supplies themselves, in curtailing use by their customers. There is deceptive reassurance in the fact that only 1,072—or 6.4 per cent—of the 16,747 public water supply systems experienced shortages; and in the further fact that fully 720—or better than two-thirds of these—served fewer than 5,000 persons. Further reading of the statistics reveals, however, that there were enough shortages in the larger systems to bring

to 16 per cent the proportion of persons served by public water supplies whose water service was curtailed. And the outlook for 1954 is even grimmer.

Bibliographic Survey of Corrosion, 1948-1949: *A compilation of corrosion abstracts. Pub. 54-1, National Assn. of Corrosion Engrs., 1061 M & M Bldg., Houston 2, Tex. (1954) 346 pp.; \$12.50*

This third in the NACE series of bibliographies of corrosion literature contains 3,512 entries, arranged in accordance with the NACE Filing System Index, and indexes to both authors and subjects. More than just a bibliography, the volume is really a collection of abstracts, since a brief summary of each article is provided. The tremendous amount of work incorporated in the book makes it and its predecessors (covering 1945 and 1946-47) invaluable in any reference library concerned with corrosion.

Proceedings of the Third Annual Water Symposium on Water Pollution, Dec. 14-15, 1953. *Bul. 43, Engineering Experiment Station, Louisiana State Univ. and Agricultural & Mechanical College, Baton Rouge 3, La. (1954) 46 pp.; paperbound; 50¢*

General papers on what pollution does to streams and industry's needs for water are mingled with specific analyses of the pollution problem in specific regions and industries of Louisiana in this printing of the proceedings of the conference. In addition, a Corps of Engineers plan to prevent diversion of the flow of the Mississippi through the Atchafalaya Basin is outlined.

(Continued on page 54 P&R)

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The Reading Meter

(Continued from page 52 P&R)

Realistic Depreciation Policy: A MAPI study. George Terborgh. *Machinery & Allied Products Inst., 120 S. La Salle St., Chicago 3, Ill. (1954) 197 pp.; \$6*

The capital goods industries continue their unflagging campaign for more liberal depreciation allowances for tax and accounting purposes with this book. And for those who are too busy to read a book, there is a 35-page pamphlet which summarizes it, and, for the press, both a 2-page summary of the summary and a press release.

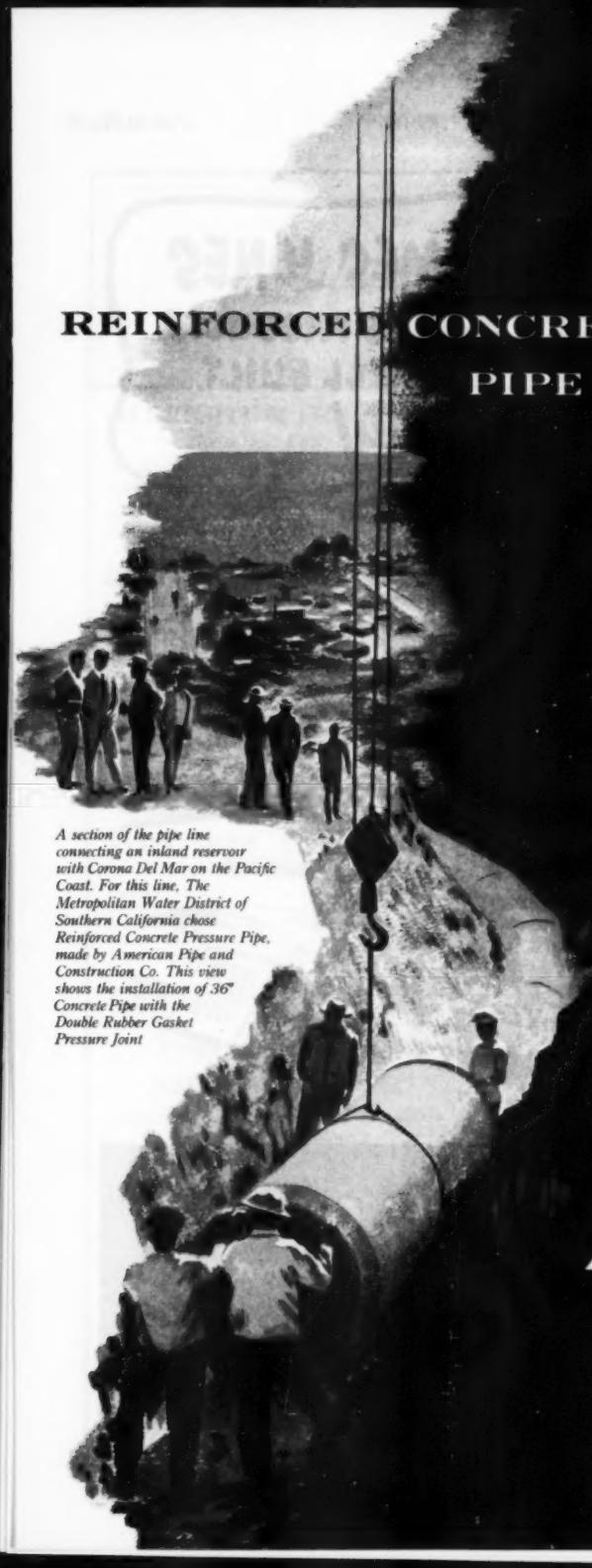
The author's approach to the "original cost or replacement cost?" question is to suggest the use of an approved set of price-index multipliers to convert original-cost values to replacement-cost values. He also urges that accelerated depreciation become the rule, rather than the exception, arguing that productive equipment actually loses value more heavily early in its life than later, with two-thirds of the value customarily having vanished at the nominal half-way mark.

Chemical Quality of Water Resources of the Conewango Creek Basin, New York. W. A. Beetem. *State Dept. of Commerce, Bureau of Business Promotion, Albany 7, N.Y. (1954) 58 pp.; paperbound; free*

The report provides analyses and other data on the waters of an Allegheny River tributary in southwestern New York State, covering 816 sq miles. It is the result of cooperation between the State Dept. of Commerce and the US Geological Survey.

Approved Minimum Standards for Design and Operation of Swimming Pools. *Div. of Health, Dept. of Public Health & Welfare of Missouri, Jefferson City, Mo. (1954) 24 pp.; paperbound*

In addition to specifying treatment procedures and recirculation requirements, many design factors having to do with safety as well as cleanliness are detailed. A thorough document for its purpose.



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A section of the pipe line connecting an inland reservoir with Corona Del Mar on the Pacific Coast. For this line, The Metropolitan Water District of Southern California chose Reinforced Concrete Pressure Pipe, made by American Pipe and Construction Co. This view shows the installation of 36" Concrete Pipe with the Double Rubber Gasket Pressure joint.



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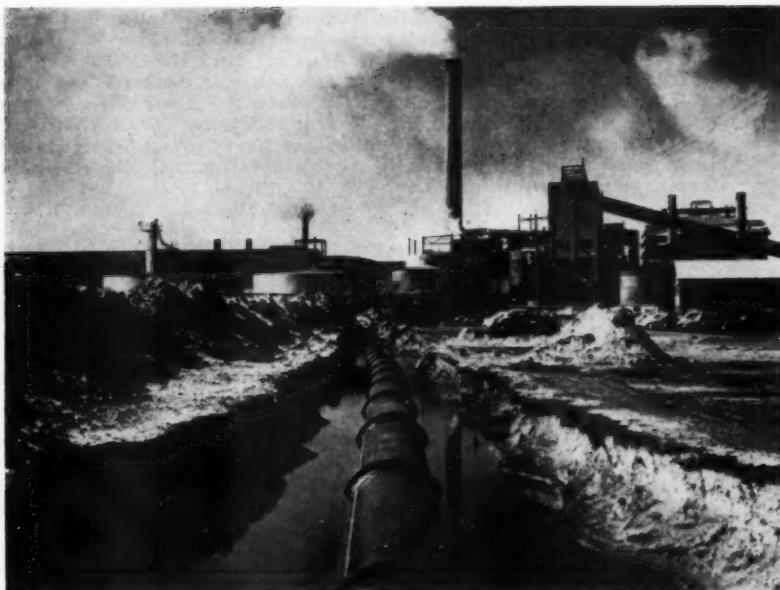
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CHEMICAL ANALYSIS

Use of Paper Chromatography for Determining Aluminum in Mineral Water. K.-E. QUENTIN. *Z. Anal. Chem.*, 140:92 ('53). Although commonly only about 1 mg of Al is present per kg of water, some spring water contains as much as 836 mg Al/kg. It is convenient to make use of chromatography, washing deposit with dil. HCl, and testing with aluminon reagent.—*CA*

Determination of Calcium and Magnesium in Lake Waters by Means of a Rotating Silver Disk Electrode. V. W. MELOCHE & R. SHAPIRO. *Anal. Chem.*, 26:347, 717 ('54). Metallic electrode system rather than graphite system is preferred from standpoint of sensitivity and absence of $(CN)_2$ interference. Range of concn. studied was 0.1–30 ppm. Best internal standard was 45 ppm Mn. Exposure conditions were 24-sec pre-spark period, 24-sec exposure, and 30% grating aperture. Const. were 0.021 microfarads of capacitance, 180 mhos of inductance, and 10 amp of radiofrequency spark current (225–235 v, input). Accuracy of measurement depended on spectral line pair employed, as well as upon concn. Same electrodes could be reused after rinsing them in concd. HCl.—*CA*

The Determination of Free and Combined Carbon Dioxide in Condensates and Boiler Feedwaters, and Standardization of the Method Against Known Amounts of Carbon Dioxide. D. PARKHOUSE. *Chemistry & Industry*, p. 1197 ('53). Method was developed for detg. CO₂ in presence of traces of carbonates, hydroxides, phosphates, NH₃, and other substances interfering with conventional methods. 5 l of H₂O for test was placed in aspirator, 10 ml 30% H₂SO₄ added, and CO₂-free H₂O bubbled through. CO₂ was absorbed in 200-ml gas-washing bottle contg. 20 ml 0.1N NaOH and 20–30 ml

CO₂-free H₂O (according to reaction $CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$) and titrated with 0.1N HCl to phenolphthalein and BDH 4.5 endpoints.—*CA*

Determination of Chloride Ions in Water by Mercuric Nitrate. G. GAD & M. MANTHEY. *Gas- u. Wasserfach*, 95:107 ('54). Under certain conditions, such as high concn. of chloride ion, endpoint in usual titration with AgNO₃ is difficult to det. Endpoint is more readily detd. with Hg(NO₃)₂ with diphenylcarbazone as indicator. Reagents required for this detn. are: [1] mixed indicator, which consists of 0.2 g diphenylcarbazone and 0.02 g bromphenol blue up to 100 ml with 95% EtOH; [2] Hg(NO₃)₂ soln., which is made by gently warming 3.084 g red HgO in 3.6 ml HNO₃ (1.42) and about 20 ml H₂O. After cooling, this soln. is made up to 1 l with water; 1 ml of this soln. corresponds to 1 mg Cl⁻. Soln. is standardized against KCl soln. contg. 2.103 g/l KCl (equal 1 g/l Cl⁻). Analysis is carried out as follows: 10 ml water is placed in Erlenmeyer flask, 1 ml of mixed indicator is added, and 0.1N HNO₃ is added until bromphenol blue color changes from blue to yellow; 1 ml excess is then added. Soln. is titrated with Hg(NO₃)₂ soln. until first permanent violet color appears. If sample is yellow in color (acid) after addn. of mixed indicator, soln. is neutralized to rosy color with 0.1N NaOH before adding 0.1N HNO₃. This analysis is not interfered with by Zn, Pb, Al, Ni, and Cr in amts. up to 100 mg/l. Cu content up to 50 mg is not harmful, nor chromate up to 10 mg. Fe should be less than 5 mg/l; interference of higher Fe contents can be avoided by adding 2 drops of 5% pyrophosphate soln. Soln. remains clear during titration, even in presence of high Cl⁻ concns. As color complex formed at end of titration is sol. in ether, thin ether layer can be used to det. endpoint in colored solns. However, soln. should be extd. with ether before detn.,

(Continued on page 66)



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(Continued from page 64)

to remove phenols, etc. Accuracy of detns. is shown to compare favorably with those with AgNO_3 .—CA

Absorptiometric Determination of Traces of Copper in Highly Purified Water. E. N. JENKINS. Analyst, 79:209 ('54). Traces of Cu^{++} down to 0.001 ppm can be measured absorptiometrically as Cu diethyldithiocarbamate in presence of citrate buffer (20% NH_4 citrate soln.) and some di-Na salt of ethylenediaminetetraacetic acid. To 500 ml of water add 0.50 g of precipitant, and, after 30 min, add 50 ml of buffer soln. and 10 ml CHCl_3 . After removing all CHCl_3 , measure optical density in Spekker absorptiometer with W lamp, No. H503, heat filters, and Ilford spectrum filters No. 601. Special procedure is necessary to avoid interference by Bi or Sb.—CA

Deuterium Content of Natural Waters and Other Substances. I. FRIEDMAN. Geochim. et Cosmochim. Acta, 4:89 ('53).

Mass spectrometric method for detn. of H/D to precision of $\pm 0.10\%$ by using as standard "normal" abundance of 1 part D in 6,700 parts H is described. Ocean waters conc. D, owing to preferential loss of lighter isotope during evapn. They range from 0.0153 to 0.0156 mole % D. Fresh waters of US vary between 0.0133 and 0.0154 mole % D. Marine waters show similar fractionation of O isotopes. Plot of H isotope ratios against O isotope ratios gives curve whose slope is ratio of vapor pressures of $\text{H}_2\text{O}/\text{HDO}$ and $\text{H}_2\text{O}^{18}/\text{H}_2\text{O}^{16}$. Measurement of Yellowstone Park fumarole gases gives min. temp. of 400° for equil. $\text{H}_2\text{O} + \text{HD} = \text{HDO} + \text{H}_2$. In abalone shell contg. org. matter, H was fractionated over D.—CA

(Continued on page 68)



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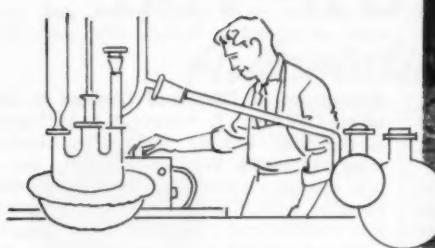


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(Continued from page 66)

it is possible to det. 10γ I or 20γ Br in presence of very large excess of other halogens. Treat sample with 0.5 ml Ca hypochlorite soln. (approx. 1*N* in respect to active Cl), 1 ml satd. NaCl, and 4 ml satd. boric acid soln.; dil. to 10 ml; heat on steam bath 10-15 min, treat with 5 ml 4% H_2O_2 ; boil 15-20 min to destroy peroxide; cool; and treat with 1-2 drops α -dinitrophenol soln. and neutralize with 0.05*N* H_2SO_4 plus 0.5 ml excess. Then treat acid soln. with 3-4 drops 10% KI and 3 drops 0.5% starch, and rapidly titrate liberated I with thiosulfate to det. I formed from reaction of IO_3^- and I ions. To det. Br, treat soln. with 3-4 ml 3*N* H_2SO_4 and 1-2 drops 5% NH_4 molybdate, and titrate with thiosulfate.—CA

Colorimetric Determination of Iron in Raw and Treated Municipal Water Supplies by Use of 4,7-diphenyl-1,10-phenanthroline. G. F. SMITH, W. H. McCURDY JR. & H. DIEHL. Analyst, 77:418 ('52). For detn. of Fe in treated water 4,7-diphenyl-1,10-phenanthroline (bathophenanthroline) is more sensitive than 1,10-phenanthroline and is applicable to detn. of 1-10 γ of Fe in 100 ml of water. Mol. extinction coeff. (22,400) is greater than that of 1,10-phenanthroline (11,100), and ferrous complex can be extd. from aq. solns. by certain solvents, e.g., isoamyl alc. and hexyl alc. For 0.01-0.1 ppm of Fe, Nessler tubes are adequate, and standards, prep'd. in isoamyl alc. by procedure described, and protected from evapn., are stable for long periods. For 0.1-5 ppm, as may occur in raw water, detn. is made spectrophotometrically, max. absorption of complex being at 533 $\mu\mu$. With procedure described, there is no known interference by Cu or other metallic cations or by commonly occurring anions.—CA

Colorimetric Determination of Manganese in Waters. E. HLUCHAN & J. MAYER. Chem. Listy, 47:846 ('53). Mn, copp'd. as $MnO(OH)_2$ with $Mg(OH)_2$, redissolved in H_3PO_4 , and oxidized with $K_2S_2O_8$ in presence of Ag^+ , is detd. as MnO_4^- colorimetrically. Up to 10 l H_2O is treated with NaOH to pH 12; ppt. is filtered, washed with 4% NaOH, dissolved on filter in 10 ml 20% H_3PO_4 , and washed with H_2O to vol. of 30 ml. Filtrate is treated with 1 ml 0.5% Ag_2SO_4 and several drops of 10% $Hg(NO_3)_2$, then with 0.1 g $K_2S_2O_8$, heated

30 min on steam bath, cooled, and, after addn. of crystal of $K_2S_2O_8$, dild. with H_2O to 50 ml.—CA

Estimation of Dissolved Oxygen in De-aerated Water. J. ARNOTT & J. MCPHEAT. Engineering, 176:103 ('53). In previous study, based on Winkler principle, use of org. solvent for concn. of liberated I before titration with $Na_2S_2O_8$ had been proposed. For simplification of method, color comparison by means of Lovibond nesslerizer was investigated and perfected. For test, 1,100 ml of water is treated by normal Winkler method, and liberated I from 1,000 ml transferred to sepg. funnel is extd. by successive addns. of 20, 20, and 10 ml of CCl_4 . Exts. are collected in 50-ml Nessler tube and compared in nesslerizer after selection of proper disk. Method is particularly useful for testing water of high purity and very low O content; difference between 0.001 and 0.003 ml O/l of water can be readily observed.—CA

The Determination of Small Oxygen Contents Dissolved in Water. II. J. VERBESTEL, A. BERGER & V. ROYER. Bul. Centre Belge Étude et Document. Eaux, No. 9, p. 529 ('50). In order to arrive at method satisfactory for trace detn. of O in water and free of zero errors encountered in previous methods, authors attempted to prep.: [1] absolutely O-free water, [2] O-free reagents or such with reproducible O content, and [3] standards with known O content. The selected procedure for complete deoxidation consisted of 3 phases: [1] boiling under vacuum alternating with N satn.; [2] removal of major portion of occluded, adsorbed, or dissolved incondensables by prolonged boiling under vacuum; and [3] repeated extn. of dissolved traces of gas by equilibration with gas atm. from which uncondensables are evacuated each time. App. used is described in detail, and theoretical considerations based on soly. coeff. of Ostwald are given. Two techniques are recommended for prepn. of O-free reagents in sealed ampules. One of these is based on repeated purging with N and intermittent partial evacuation; second is applicable to relatively coned. aq. solns. which have no appreciable vapor pressure, and consists in sealing properly prep'd. and filled ampules under vacuum.—CA

(Continued on page 70)

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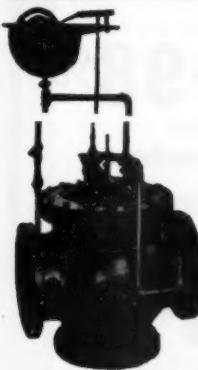
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(Continued from page 68)

New Method for Determining Dissolved Oxygen in Waters Containing Active Reducing Agents. K. WICKERT & E. IPACH. Z. Anal. Chem., 140:350 ('53). Add aq. Br, oxidize reducing agent present, add sulfosalicylic acid to take care of excess Br, and det. DO by tolidine-Mn⁺⁺ method.—CA

Determination of Sodium and Potassium in Natural Waters. M. V. TOVBIN & F. G. DYATLOVITSKAYA. Ukrain. Khim. Zhur., 18: 657 ('52). Detcn. of Na and K by means of ion-exchange resins is described in detail. For best results, Ca and Mg are ptd. and filtrate, contg. salts only of Na and K, is passed through cationic resin and amt. of liberated acid is titrated. For satisfactory retention of Na and K, test soln. (100 ml) is made weakly acidic with AcOH, treated with 2-3 ml 1N NH₄ oxalate and 2-3 ml 1N NH₄OAc, followed by 3-4 ml 2% alc. 8-hydroxyquinoline; after 3-4 min soln. is treated with dil. NH₄OH until NH₃ odor is evident, heated to boiling, let stand 2-3 hr,

and filtered; wash waters and filtrate are evapd. to dryness, heated to 300° (45 min), taken up in H₂O, and passed through resin bed. Washings are titrated with methyl orange indicator. Pt dishes are advised for evapn.; porcelainware gives high results.—CA

The Determination of Total Hardness in Drinking Water According to the Versenate Method. M. W. E. EVERE & J. S. N. CRAMER. Chem. Weekblad, 50:218 ('54). Method of Sijderius [Jour. AWWA, 44:11: 72 P&R] in which Schwarzenbach's NH₃-NH₄Cl buffer was replaced by sodium carbonate buffer gives incorrect results at temps. above 18° (Schwarzenbach recommended titration at 40°). Error is due to pptn. of CaCO₃. At 18° consistent results are obtained because less CaCO₃ is ptd. and also there is compensating error due to slow formation of complex. Method of Rijks Inst. voor Volksgezondheid avoids pptn. of CaCO₃, and also avoids interference by Fe⁺⁺. Dis-

(Continued on page 72)

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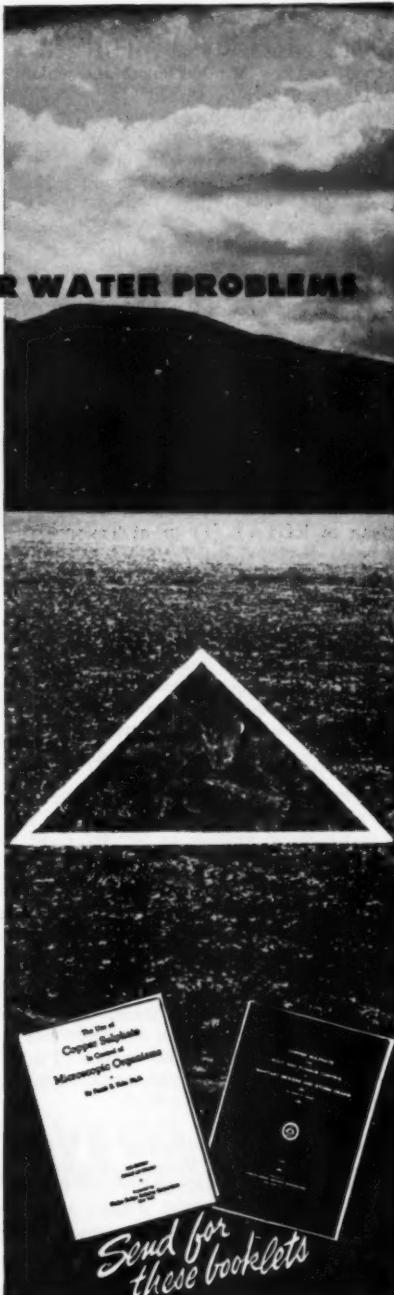
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(Continued from page 70)

solve 8.91 g NH_4Cl , 94.6 ml NH_3OH (density 0.88), and 6 g Mg Versenate and make up to 1 l. Buffer soln. should have pH 10. Dissolve 10 g Na Versenate ($\text{C}_{10}\text{H}_{14}\text{N}_2\text{O}_8\text{Na}_2 \cdot 2\text{H}_2\text{O}$) and make up to 1 l. Standardize against 25 ml of standard soln. prep'd. from 200.2 mg CaCO_3 dissolved in 40 ml 0.1N HCl and dild. to 100 ml. Dissolve 0.5 g Eriochrome black and 2.25 g $\text{NH}_3\text{OH} \cdot \text{HCl}$ in 96% alc. to 100 ml. Titrate HCO_3^- , add Br_2 , and warm mixt. for about 30 min on steam bath. Cool to about 40°, add 4 ml of buffer soln., and, just before titration, add 6 drops of indicator soln. and titrate with Na Versenate soln.—CA

A New Method for the Determination of the Hardness of Water. P. CARBONI. Chimica e Industria [It.], 35:562 ('53). Hardness of water due to Ca and Mg ions is detd. by causing turbidity in dil. soap soln. to disappear by addn. of soln. of Trilon B (Na salt of EDTA) (I) or of Trilon BS (free acid) dissolved in 2N NaOH and dild. with H_2O . To 1 l water (or fraction) add 20 ml (or corresponding fraction) of 5% aq. soln. of coml. olive oil soap, heat to 40–45°, and titrate with I soln. (approx. 5%) till soln. is completely clear; 2–3 drops are subtracted from vol. of I used. With 1 l of water, no. of ml of I soln. gives hardness directly in French degrees (equal 10 ppm CaCO_3 each). I soln. is standardized by adding to 194 ml distd. H_2O 2 ml stock CaCl_2 soln. [prep'd. by evapn. to dryness of 10 kg pure CaCO_3 dissolved in 105 ml 2N HCl and soln. of residue in 500 ml distd. H_2O ; 10 ml soln. added to 990 ml distd. H_2O gives 1 l of water of 20-deg (Fr.) hardness] and about 4 ml of soap soln., heating to 40–45°, and titrating with I soln. until last 2–3 drops do not yet render soap soln. completely clear. I soln. is "normal" when 4 ml is required to dispel turbidity of 200 ml of water of 20-deg hardness. Method is convenient, more exact than older methods (approximation to 0.1 deg), not influenced by presence of alkali salts, and suitable for analysis of brackish water.—CA

Separation and Concentration of Trace Metals From Natural Waters: Partition Chromatographic Technique. D. E. CARRITT. Anal. Chem., 25:1927 ('53). CCl_4 -dithizone soln. held on cellulose acetate support is immobile phase and aq. sample soln.

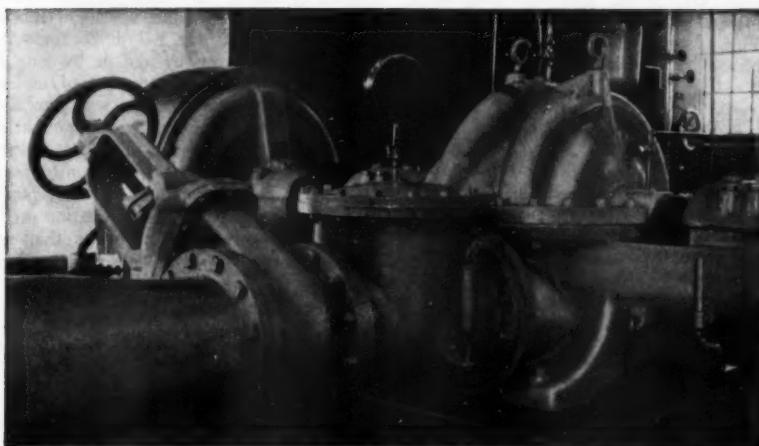
is mobile phase. Recoveries of Pb, Zn, Cd, Co, Cu, and Mn singly and in combinations from solns. of pH 7.0 were studied, with concn. factors up to 1,000 achieved. All elements studied were detd. polarographically, except Mn, which was detd. colorimetrically. Partial sepn. was achieved by elution with proper reagents. All were completely removed by elution with 1M HCl, except Co and Cu, which were eluted with concd. ammonia. Acid-washed column could be reused, but concd. ammonia destroyed column.—CA

Mass Spectrometer Determination of Volatile Contaminants in Water. F. W. MELPOLDER, C. W. WARFIELD & C. E. HEADINGTON. Anal. Chem., 25:1453 ('53). Method has been developed for quant. and qual. detn. of volatile contaminants which affect taste and odor of water. Petroleum products, such as natural gas, gasoline, kerosene, and furnace oil, can be identified by this method. Hydrocarbons boiling below 400° are detd. at concns. as low as 0.01 ppm. Method consists of stripping volatile compds. from boiling water with H, condensing vapor in liquid N trap, and analyzing condensate in mass spectrometer. Method can be extended to det. volatile compds. other than hydrocarbons. About 3.5 hr is required for single analysis.—CA

Rapid Procedure for Estimating Organic Materials in Industrial Wastes. J. G. NIEDERCORN, S. KAUFMAN & H. SENN. Sew. Ind. Wastes, 25:950 ('53). O-consumed detn. not subject to interference by chlorides was attained by combining alk. permanganate method of Benson and Hicks with that of Stamm. Values obtained generally were approx. 60% of corresponding 5-day BOD values, but precision was good. Susceptibility of various org. substances to oxidation under conditions of detn. apparently varied with chem. structure. Chief value of this procedure will probably lie in indicating variations in pollutional strength of specific waste or in comparing efficiencies of treatment on particular waste.—CA

Determination of Oil Content of Condensate. H. HOLLÄENDER. Seifen-Ole-Fette-Wachse, 79:546 ('53). Oil content of steam condensate is detd. by comparing fluorescence under ultraviolet light with that of known

(Continued on page 74)



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(Continued from page 72)

standards; method is accurate to 0.02 mg/l. Standards are prep'd. by dilg. condensate whose oil content has been detd. by time-consuming Zschimmer method and can be stored for year in well stoppered bottles and in dark.—CA

BACTERIOLOGY

Improved Methods for Determining the Most Probable Number of *Bacterium coli* and of *Streptococcus faecalis*. E. CHILDS & L. A. ALLEN. J. Hyg., 51:468 ('53). Three methods were investigated for determining MPN, using lactose-bile salts broth for *Esch. coli* and glucose-yeast extract-azide broth for *Str. faecalis*. In "direct" method, inoculated tubes of medium were incubated directly in water bath, at 44°C for *Esch. coli* or at 45°C for *Str. faecalis*. In "subculture" method, primary incubation at 37°C was followed by subculture of positive tubes to tubes of fresh media which were incubated at higher temperature. In "resuscitation" method each medium was divided into 2

parts; inoculum was mixed, in McCartney bottles or tubes, with first part of medium, containing sugar and peptone, and mixture was held at 37°C for 1-2 hr to resuscitate organisms weakened by age or by long immersion in water; second part of medium, containing bile salts or azide, was then added and bottles or tubes were incubated at 44° or 45°C. With samples of polluted waters subculture method gave significantly higher counts than direct method for *Str. faecalis* but not for *Esch. coli*. Resuscitation method gave significantly higher results than subculture method for both organisms, required less time for completion, and was specific for organism concerned. These results were obtained with media containing 0.003% bromcresol purple as indicator; neutral red was found to be inhibitory.—PHEA

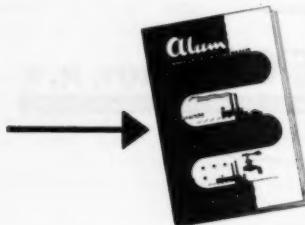
The Use of Glucose Inorganic Salts Media in the Classification of the Coli-Aerogenes Bacteria. I. The Methyl Red and Voges-Proskauer Reactions. M. T.

(Continued on page 76)

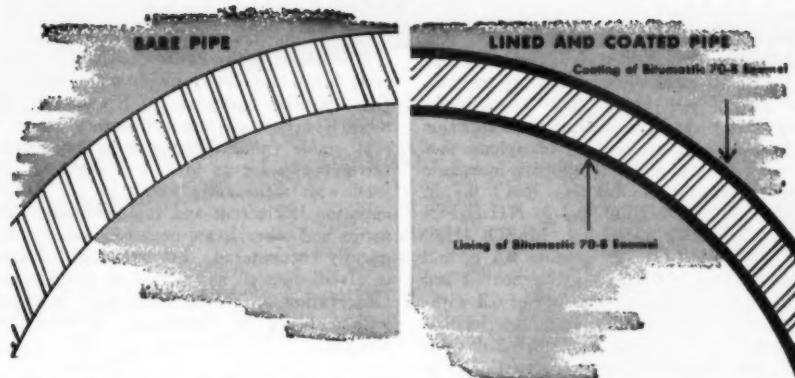
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(Continued from page 74)

A. FOUAD & T. RICHARDS. Proc. Soc. Applied Bact., 16:1:35 ('53). Chemically defined glucose ammonium phosphate medium gave methyl red (MR) and Voges-Proskauer (VP) reactions which were superior to those in glucose peptone phosphate medium. Formula of basal glucose-inorganic salts medium is as follows: NaCl 0.5 g, K₂HPO₄ 0.5 g, KH₂PO₄ 0.2 g, NH₄H₂PO₄ 0.2 g, MgSO₄·7H₂O 0.02 g, MnSO₄·4H₂O 0.002 g, FeCl₃ 0.0005 g, glucose 0.5 g, and distilled water 100 ml. When prepared and autoclaved, this medium had pH of 6.8 without further adjustment. Optimum incubation conditions for both tests were 3 days at 30°C, and both tests were carried out on same culture tube; conventional method was used for testing with MR, and O'Meara's method was adopted for testing for acetoin. Majority of strains of coli-aerogenes group encountered seem to fall into one or other of two groups: either they produce good deal of stable acid and trace or zero amounts of acetoin (MR +, VP -), or else they produce some acid, much of which is subsequently utilized for production of appreciable amounts of acetoin, so that acidity after 3-5 days is low (MR -, VP +). Strains do exist, however, commonly on vegetation, which are capable under certain cultural conditions of forming quite large amounts of acid from glucose and maintaining pH of 5.5 or less (MR ± to +) for at least 5 days, while at same time producing enough acetoin for VP reaction to be clearly positive. In spite of this, synthetic medium gave negative correlation between two reactions with 34 out of 35 strains that were positive to both tests in peptone medium. Addition of glutamic acid to medium helped to eliminate doubtful positive MR reactions, but seemed to suppress acetoin production by weak VP positive strains.—BH

Use of Tergitol-7 Triphenyl Tetrazolium Chloride Agar as the Coliform Confirmatory Medium in Routine Sanitary Water Analysis. W. L. KULP, C. MASCOLI & O. TAVSHANIAN. Am. J. Pub. Health, 43: 1111 ('53). Authors suggest that T-7 agar replace Endo and EMB agars as confirmatory medium for coliforms in standard method of water analysis. Like Endo and EMB, T-7 agar indicates likely IMViC reactions of isolate, but with considerably greater accuracy. Considering all properties, T-7 agar

presents following advantages over Endo and EMB: [1] it is extremely restrictive, apparently being completely inhibitory to common Gram-positive bacteria; [2] it exerts no inhibitory action on any coliforms; [3] it is very stable (poured plates were kept under refrigeration for as long as 6 wk and still used with satisfactory results); [4] differentiation is clearcut and rapid between coliforms and other Gram-negative bacteria frequently encountered. Formula for T-7 agar is given, as well as method of preparation. Observation of surface colonies is made within 12-24 hr incubation at 37.5°C.—PHEA

The Incidence of *Bacterium coli* in Farm Water Supplies. S. B. THOMAS ET AL. Proc. Soc. Applied Bact., 16:1:30 ('53). In coliform examination of farm water supplies 85% of 24-hr positive tubes at 37°C contained *Esch. coli* type I, and as many as 23% of tubes showing positive reactions during second day at 37°C contained this organism. Criterion of presence of organism in presumptive positive tube was production of acid and gas in MacConkey broth at 44°C in 48 hr of incubation. It appears that laboratory work involved in examination of farm water supplies necessitates primary incubation of 48 hr and confirmatory incubation of 48 hr. Observation for positives and subculture at intermediate periods would involve more time and labor, but, on other hand, *Esch. coli* strains developing in first 24-hr incubation may be overgrown by other coliform types developing subsequently. Authors are therefore investigating survival of *Esch. coli* type I in mixed cultures in MacConkey broth incubated for 48 hr and 72 hr at 37°C.—BH

Bacteriological Examinations of Water and Their Interpretation. R. D. STUART. Munic. Util. (Can.), 92:2:26 ('54). History of water examn. outlined. Leeuwenhoek first detected life in water in 17th century, while John Snow in 1849 was first to correlate epidemic disease with contam'd. water. In 1896 Remlicher and Schneider isolated typhoid bacilli from naturally contam'd. water and in 1892 Theobald Smith suggested coliform organisms as indicator of possibility of presence of pathogenic intestinal bacteria. Technique of examn. and its significance also outlined and discussed.

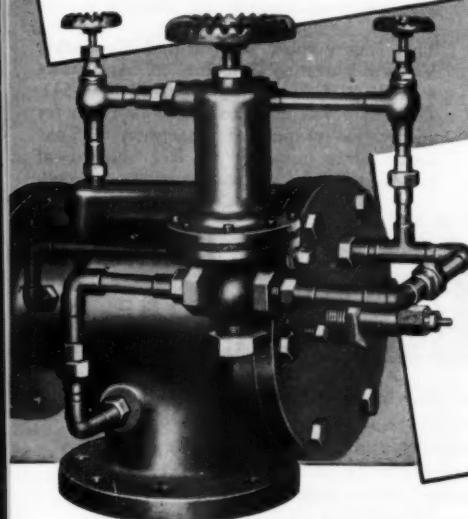
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(Continued from page 76)

Bacterial count of no significance if drainage area free from human contamn.; if contamn. possible, high counts may be direct warning of danger. Except in special instances, plate counts not worth time spent on them. Feces contain million coliform organisms per g. Presumptive, confirmatory, completed and differential coliform tests discussed. If presumptive test using lactose broth pos. (author prefers MacConkey medium), almost 90% probability that coliforms present. Pos. completed test confirms their presence. However, neg. tests do not insure their absence, and no tests available to distinguish between coliforms of human and animal origin. Sole reliance should not be placed on coliform tests; local sanitary conditions must also be considered. Coliform bacteria probably harmless except to infants, and supply should be condemned on account of their presence only if human pollution possible. Pos. presumptive tests which do not confirm add to difficulty of interpretation. Author believes such tests indicative of more remote pollution. May indicate

intermittent contamn. at considerable time intervals. Repeated examns. may show that bacteria responsible are simply established in local soil or vegetation and thus are of no significance. Care must be taken to avoid contamn. during sampling, and sample must be examd. promptly. Bact. tests reveal only condition of sample at time of examn. The less the agitation and the more uniform the temp. during interval between collection and examn., the greater the probability of reliable result. Most satisfactory temp. is close to freezing point, obtained by packing in ice. Bact. examn. does not provide absolute answer to question of suitability of water for human consumption; must be supplemented by sanitary survey.—R. E. Thompson

The Inactivation of Purified Coxsackie Virus in Water by Chlorine. N. A. CLARKE & P. W. KABLER. Am. J. Hyg., 59:119 ('54). This study was made to determine times for inactivation of purified suspension of Coxsackie virus in water by free chlorine at various temperatures and hydrogen ion con-

(Continued on page 82)



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(Continued from page 78)

centrations. Results showed that inactivation times were dependent on temperature, hydrogen ion concentration, and chlorine concentration, and that data followed disinfection pattern of bacteria, $C^n T = A$, where C is chlorine concentration, n is concentration exponent, T is time, and A is constant. In general, from 7 to 46 times as much free chlorine was required to inactivate virus as to kill suspension of *Esch. coli* cells.—PHEA

Survival of *Salmonella* in Sea Water. R. BUTTIAUX & T. LEURS. Bul. Acad. Nat. Med., 137:457 ('53). Authors isolated *Salmonella montevideo* (10-20/1) from sea water near bathing beach. They investigated survival of various types of *Salmonella* which were added from laboratory cultures to freshly collected samples of North Sea water not containing extraneous organic matter. 1 hr after collection, 1-l samples of sea water were inoculated with washed suspensions of *Salmonella* from nutrient agar slopes and left in Erlenmeyer flasks at 18°C in diffuse sunlight; flasks were shaken every 20 min. Survival of added *Salmonella* was determined at intervals by tryptose agar pour plate counts, and results were compared with control counts from filtered spring water inoculated with same organisms. First series of experiments was done with *S. typhi*, *S. paratyphi B*, and *S. enteritidis*. With initial counts of between 150 and 500 organisms per ml of sea water, all 3 organisms showed 50-60% survival at 44 hr, while all showed mortality of over 90% in same time in control experiments with spring water. In second series of experiments, it was found that survival of *S. typhimurium* in sea water was not affected by shaking, oxygenation,

or addition of small quantities of broth.—BH

Membrane Filter Procedure Applied in the Field. E. J. LAUBUSCH, E. E. GELDREICH & H. L. JETER. Pub. Health Rpts., 68:1118 ('53). During national emergencies, whether wartime or natural disasters, quick, reliable field test is desirable for positive identification of microorganisms responsible for pollution of water supplies. Best method appears to be use of membrane filter with either 2-oz ointment tin or disposable plastic petri dish. Field sterilization can be accomplished by use of flaming alcohol, incomplete combustion of methyl alcohol, or pressure cooker (one normally used for canning). Culture media can be kept in screw-capped tubes until needed. There is alternate piece of equipment to be used in field for each type of apparatus used in laboratory with exception of electric vacuum pump. Substitution of vestlike garment, which adheres closely to body, for standard incubator is also described. Results of using both plastic petri dishes and ointment tins showed that either could be used interchangeably. Coliform recoveries from field vest type incubator compared favorably with those from conventional incubation.—PHEA

Bacteria in Water Which Utilize Phenol as a Sole Source of Carbon. R. FERRAMOLA & J. ELENA D. M. Rev. Obras Sanit. Nacion, 17:113 ('53). From waters of La Plata and Riachuelo Rivers were isolated 119 species of bacteria. Biochem. tests and morphological characteristics placed these in following genera: *Pseudomonas*, *Achromobacter*, *Micrococcus*, and *Vibrio*. All bac-

(Continued on page 84)

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(Continued from page 82)

teria isolated grew well at room temp., in mineral-salts medium contg. from 0.02 to 0.05% phenol and KNO_3 or $(\text{NH}_4)_2\text{SO}_4$ as source of N. Concn. of phenol was found to be important. Below 0.01% growth was extremely slow, and at 0.1% marked inhibitory action was noted.—CA

CORROSION

Corrosion Control of Steel Equipment. T. R. B. WATSON. Can. Chem. Processing, 37:10:46 (Sep. '53). Metal surfaces in contact with soln. or moisture tend to form electrolytic cells, and resulting current is cause of most corrosion. Slight difference in elec. potential between adjacent areas may be due to variations in metal compn., scale deposits, mill scale, rust deposits, differences in soil compn., access of O, or any combination of these. Current flows from more neg. (anodic) areas through water or soil to more pos. (cathodic) areas and back through metal itself. Corrosion occurs at anodic areas only, and rate is directly proportional to current strength—1 amp/yr dissolves about 20 lb steel. Tubercles which form over pits aggravate corrosion by forming O concn. cells. Two methods of control apparent: [1] prevent access of moisture, [2] prevent flow of elec. current. Former involves correct selection of coatings for particular situations and proper application. By rendering whole surface cathodic, all local anodes overpowered and corrosion ceases. Power may be supplied by gasoline-driven generator or rectifier. Anodes may be of any elec. conductor—modern trend to graphite rods. Mg very electroneg.; if large piece buried near steel pipe and connected to it with Cu wire, current will flow from Mg through earth to pipe without application of external power. Similarly, Mg is used to protect hot-water storage tanks. Coated pipe requires far less protective current, only enough to protect metal at "holidays" in coating. Coated and wrapped 10" line may be protected by rectifier stations every 40 mi, each draining about 6 amp, or, alternately, by about 4 Mg anodes per mi. Similar bare pipe would require about 16 amp/mi, or 1 anode every 20'. Current density required varies in different media—generally 1-3 ma/sq ft sufficient in soil or fresh water. Commonly accepted criterion is that protective current should depress potential of pipe at least 0.3 v, based on assumption that no local corrosion cell will have potential higher than 0.3 v. Practical

measure in existing plants is to install Mg anode every time excavation made to fix leak. In this way, protection concentrated where needed most, and, as time goes on, whole system rises in potential and leak frequency decreases. Cathodic protection of elevated tank may be provided by suspending 3-8 anodes from roof, equally spaced, to protect bowl, and single long anode in riser, with small rectifier mounted on tower leg. When Al anodes specified, frequently of such diam. as to be consumed and require replacement yearly. Replacement of graphite anodes unnecessary. When ice damage possible, electrodes must be removed every fall. No appreciable corrosion occurs in cold water during winter.—R. E. Thompson

Corrosion Control in Water Systems. H. H. UHLIG. Ind. Eng. Chem., 44:1736 ('52). Economic importance of corrosion protection in water systems is stressed. Cathodic protection should find many economic applications in controlling corrosion of water works equipment and will probably be applied more generally. Improvement of corrosion-protective paints and org. coatings can be anticipated. Future use of Ti offers promise; when price approaches that of stainless steel, it will be used in wrought and cast form and as clad coating over steel. —CA

Influence of Sulfate-reducing Bacteria on the Corrosion Potential of Iron. J. N. WANKLYN & C. J. P. SPRUIT. Nature (Br.), 169:928 ('52). Role of sulfate-reducing bacteria in corrosion of iron has been investigated by measuring changes in potential of iron electrode immersed in sterile medium under autotrophic and heterotrophic conditions. After steady potential was attained under anaerobic conditions in autotrophic medium, medium was inoculated with sulfate-reducing bacteria, but there was little or no change in potential. When sodium lactate was added to provide organic hydrogen donor, potential became more negative and this was followed by increase in potential to steady value more positive than initial steady value. It was concluded that, under autotrophic conditions, bacterial activity has little effect on corrosion potential. When lactate was added, anodic depolarization occurred, probably as result of increase in production of sulfide following introduction of hydrogen donor, sulfide acting as anodic stimulator.—WPA



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Nebraska's Zero Hour

To the Editor

The Nebraska Section is indeed proud and happy to have received advice that the ten thousandth member of the Association is one of our own Nebraskans.

We welcome Mr. F. M. Merritt, Water Commissioner of Chadron, Neb., to mem-

bership in the Association as "Mr. Ten Thousand." Mr. Merritt, by the way, narrowly missed being the Nebraska Section's "Mr. One Hundred," since we were just advised that the membership of our Section had reached that figure. Mr. Walter Dunlap of Lexington, Nebraska, is our "Mr. One Hundred."

The vigorous and rapidly growing 1% of the Association which Nebraska represents wishes to take this opportunity to congratulate Mr. Merritt. We are proud to claim "Mr. Ten Thousand" and we look forward to working in the Association for another 10,000 members nationally and another two or three hundred in our own Section.

RALPH LANCASTER
Director Nebraska Section
Supt., Board of Public Works
Kearney, Neb.; Aug. 12, 1954

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— a water soluble Glassy Sodium Phosphate
of standardized composition; specified for all
water treatment applications indicating
Sodium Hexametaphosphate or Sodium Tetraphosphate

A leading primary producer of Sodium Fluoride
and Sodium Silicofluoride (sole producer of Sodium
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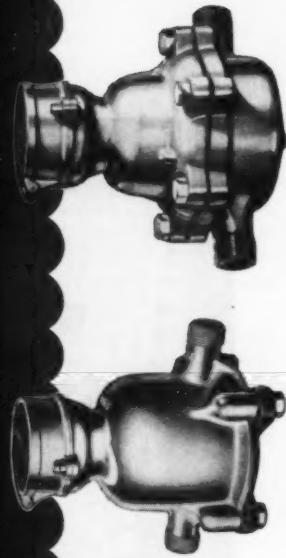
SAMPLES AND DATA ON REQUEST.

BLOCKSON CHEMICAL COMPANY
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Water is Vital...

BADGER meters conserve it BETTER!



AMERICA'S steel production now tops 72,000,000 tons annually . . . yet it actually takes more water than iron ore to produce today's steel. Badger meters conserve water for such vital needs . . . measure water usage precisely . . . help eliminate water waste in thousands of communities. They make sure that homes and industrial projects alike receive a fair share of the supply, and pay a fair price for the water used. Thus, Badger meters actually help keep water departments self-supporting for thousands of communities. No wonder waterworks men everywhere praise Badger meters . . . recognize them as the meters that save water, work and money — *all ways*.

BADGER Water Meters

Badger Meter Mfg. Co.

Milwaukee 45, Wisconsin

"Measures the water of the world"



CHANGES IN MEMBERSHIP



NEW MEMBERS

Applications received July 1-31, 1954

Allen, Thomas F., Safety Engr., Dept. of Water & Sewers, Rm. 403 City Hall, Chicago, Ill. (July '54) *M*

Barrett, W. L., City Engr., City Hall, Fredericton, N.B. (July '54)

Bohr-Manning Corp., Thomas J. McMahon, Services Engr., Troy, N.Y. (Corp. M. July '54) *MRPD*

Bell, Carlos G., Jr., Asst. Prof., Northwestern Univ., Technological Institute, Civ. Eng., Evanston, Ill. (July '54) *MRPD*

Bergerson-Caswell, Inc., Fred Davis, 13120 Wayzata Blvd., Minneapolis 16, Minn. (Assoc. M. July '54)

Blackwell, Albert L., Engr., Portland Cement Assn., 347 Madison Ave., New York, N.Y. (July '54) *RD*

Broadhurst, William L.; *see* High Plains (Tex.) Underground Water Conservation Dist. No. 1

Burnham, M. C.; *see* Cullen (La.) Water & Development Co.

Caples, Martin H., Pres., Princeton Junction Water Co., Scott Ave., Princeton Junction, N.J. (July '54) *MR*

Chapman, W. C., Supt., Mill Tech. Dept., Union Bag & Paper Corp., Box 570, Savannah, Ga. (July '54)

Collins, Richard C., Sales Engr., De Laval Turbine Pacific Co., 535-1st Ave. W., Seattle, Wash. (July '54) *D*

Creason, Howard Lee, Supt., Beaumont Irrigation Dist., 157 E. 5th St., Beaumont, Calif. (July '54) *M*

Cullen Water & Development Co., M. C. Burnham, Secy., Treas., Cullen, La. (Corp. M. July '54) *M*

Davis, Fred; *see* Bergerson-Caswell, Inc.

Deblison, William H., Supt. of Water, Caledonia Power & Water Board, Glace Bay, N.S. (July '54)

Deeney, Patrick H., Supt.-Gen. Mgr., Water Dist. No. 20, King County, 1822 S. 120th, Seattle 88, Wash. (July '54) *MRPD*

De Nat, Murray, Chief Clerk, Bureau of Water Register, Dept. of Water Supply, Gas & Elec., Municipal Bldg., New York 7, N.Y. (July '54)

District Federal Dirección General De Obras Hidráulicas, Fernando Hiriat B., Director Gen., Edificio Nuevo del Dpto. del D.F., Mexico 1, D.F., Mexico (Corp. M. July '54) *MRPD*

Fogg, Eugene, Water Supt., 18516 Jefferson Ave., Riverview, Mich. (July '54) *M*

Fontana, Louis F.; *see* Irving Subway Grating Co., Inc.

Ford, Arthur C., Comr., Dept. of Water Supply, Gas & Electricity, Municipal Bldg., New York 7, N.Y. (July '54) *MRPD*

Gayton, Donald V., Jr., Div. Mgr., Fischer & Porter Co., 5403 Sheila St., Los Angeles 22, Calif. (July '54) *P*

Golden, Joseph F., Cons. Engr., Golden & Bryant, Box 1329, 1461 State St., El Centro, Calif. (July '54)

Gorham, Charles H., Civ. Eng. Asst., Dept. of Water & Power, 207 S. Broadway St., Los Angeles 12, Calif. (July '54) *D*

Hammar, Alfred F., Supt., Water Works, 117 N. 10th St., Box 230, Santa Paula, Calif. (July '54) *MRPD*

Helton, Harry T.; *see* Munster (Ind.)

Herbert, Harry C., Design Engr., Glace & Glace, 1001 N. Front St., Harrisburg, Pa. (July '54) *PD*

High Plains Underground Water Conservation Dist. No. 1, William L. Broadhurst, Chief Hydrologist, 1628-B 15th St., Lubbock, Tex. (Corp. M. July '54) *R*

Hiriat B., Fernando; *see* Distrito Federal Dirección General de Obras Hidráulicas

Hockett, William A., Director of Sales, Wallace & Tieran Inc., Belleville, N.J. (July '54) *P*

Hoffmann, William F., Jr., Contracting Engr., Pittsburgh-Des Moines Steel Co., 1215 Praetorian Bldg., Dallas, Tex. (July '54)

Holster, William, Asst. City Engr. & Director of Public Works, Clifton, N.J. (July '54) *PD*

Hunt, H. Harvey, Sales Engr., The Dorr Co., 2631 University Ave., St. Paul 14, Minn. (July '54) *P*

Irving Subway Grating Co., Inc., Louis F. Fontana, Sales Mgr., 50-09-27th St., Long Island City, N.Y. (Assoc. M. July '54)

Johnson, Rufus C., Cons. Engr., Box 282, Douglas, Ga. (July '54) *PD*

Lansdale, Dyke, Pres., Dyke Water Co., 11065 Penn Ave., Garden Grove, Calif. (July '54) *MD*

Lashbrook, Charles Arthur, Pres., Oklahoma Testing Labs., 310 N. Klein, Oklahoma City, Okla. (July '54) *P*

Lee, Harry, Materials Engr., US Navy, Dist. Public Works Office, 12 ND, Code DB200, San Bruno, Calif. (July '54)

Lesher, Carl E., Jr., Staff Engr., H. K. Ferguson Co., Ferguson Bldg., Cleveland 14, Ohio (July '54) *MRPD*

Lyon, Herbert L., Asst. Secy. & Asst. Treas., General Waterworks Corp., 701 Main St., Pine Bluff, Ark. (July '54) *M*

Marx, Jerome J., Dist. Mgr., Lewin-Mathes Co., 18509 James Couzens, Detroit 35, Mich. (July '54)

Mascitti, Frank L., Sales Engr., Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Ave., Philadelphia 44, Pa. (July '54) *MRPD*

(Continued on page 94 P&R)

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Well Washed and Carefully Graded to Any Specification.

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Lead Melting Furnace**

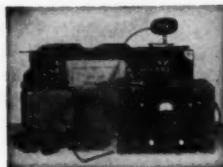


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Best quality asbestos rope, brass caps attached to each end. Equipped with clamps.

**M-D Cut-In Connections
for Sewers**

A light cast iron fitting with bell end for connecting house service with main sewer pipe without necessity for placing a Y-branch or T-branch in the sewer line.



Leak Detector

A truly fine instrument designed to solve even the most difficult leak detecting problem.

Calking Tool Outfit



For water mains up to 12". Strong leather bag. Keeps the right tool for every job within easy reach.

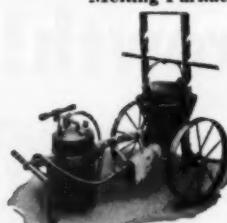


**Test Plugs for
Bell or Spigot End
Cast Iron Pipe.**



On this page are shown only a few of the hundreds of items to be found in the POLLARD Catalog. Write for a copy of Catalog No. 25K.

**Portable Lead
Melting Furnace**



A handy outfit for quick action, equipped with gasoline burner.

Pipe Cutter

Inexpensive way of cutting pipe. Every wheel in contact with the pipe is a cutting disc, so cutter need be moved only a short distance to cut entirely around the pipe.

Tapax



The original manhole cushion. Takes the bang out of manhole covers.



M-Scope Pipe Finder

It's easy to locate a buried pipe line with this handy pipe finder.

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WATER Paces

Lakeland's Business Growth!

Allis-Chalmers Helps 'World's

THE "WORLD'S CITRUS CENTER" is being helped by Allis-Chalmers in the race to keep water works ahead of population growth. In ten years, Lakeland's population has increased 70 percent, meters have doubled, and gallonage pumped has nearly tripled!

Lakeland is so named because of the 12 lakes within its city limits. It is near the geographical center of Florida, in Polk county . . . producer of a third of all Florida citrus, two thirds of U. S. phosphate, and more cattle than any other county in the state.

Lakeland has learned by experience the wisdom of depending on Allis-Chalmers for a complete range of public works equipment. Some of their A-C equipment has been in operation for over 30 years and maintenance has been "practically nil." A-C equipment at Lakeland ranges from three turbine-generators through transformers, m-g sets, and controls to motors and pumps of many sizes.

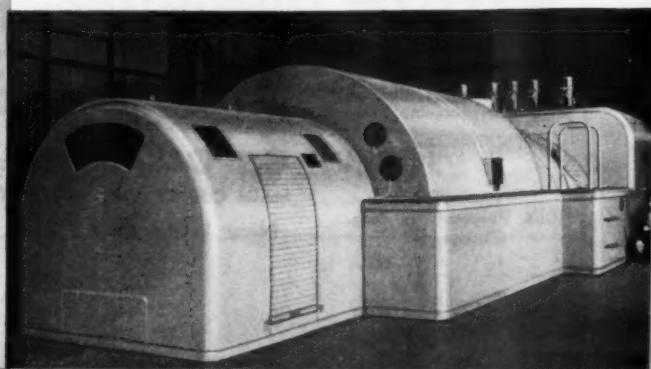
When *your city* plans expansion or modernization, do as Lakeland and other leading cities are doing — take advantage of Allis-Chalmers experience as builder of the world's widest range of public works equipment. Literature on all products available; Public Works Bulletin 25C6607A and Pump Bulletin 08B6146B just off the presses. For your copies, just call your nearest A-C sales office or write to Allis-Chalmers, Milwaukee 1, Wisconsin.

A-4221



POWER TRANSFORMERS were furnished by Allis-Chalmers. Those above are 833 kva, single phase, self-cooled units in Lakeland sub-urban substation. Other electrical equipment supplied includes controllers for the 150 hp deep well pump motors.

NEW POWER HOUSE features Allis-Chalmers 20,000 kw steam turbine generator unit. In addition to the steam turbine, hydrogen cooled generator, main and pilot exciters, and hydrogen control equipment, A-C also furnished the three 6x4 in., 450 gpm, 1150 psi boiler feed pumps.

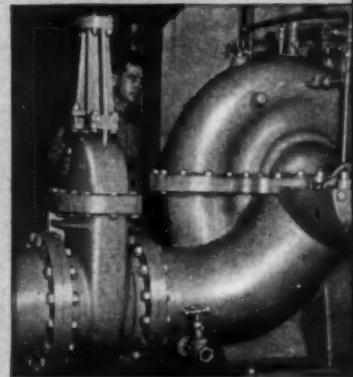
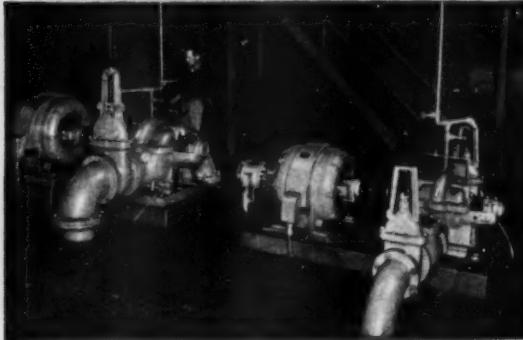




Citrus Center' Expand Water Works

LAKELAND FROM THE AIR, looking east. Over 600,000 people live in a 50 mile radius from Lakeland, Fla. Old power house, containing two Allis-Chalmers 5000 kw steam turbine generator units and associated equipment, is on left shore of Lake Mirror in center of above photograph.

CITY MAINS ARE SUPPLIED by Allis-Chalmers pump-motor teams ranging in capacity from 2000 to 4000 gpm each. Typical setup shown below: at left is a 12 x 10 in. pump rated 4000 gpm at 160 ft head, driven at 1800 rpm by 200 hp motor. At right is a 2000 gpm, 8 x 8 in. pump driven by a 100 hp, 1800 rpm synchronous motor.



PUMPS RANGE IN SIZE from $1\frac{1}{4}$ x $1\frac{1}{4}$ in. to this 16 in., 4000 gpm, 16 ft head unit furnishing condenser cooling water in old power house. Here Allis-Chalmers supplied two 5000 kw steam turbine generator units, boiler feed and condenser circulating water pumps, and crane m-g set.

ALLIS-CHALMERS

Builders of the World's Widest Range of Public Works Equipment



(Continued from page 92 P&R)

McDonald, Gordon A.; *see* West Bridgewater (Mass.) Board of Water Comrs.

McKee, James W., Chief Pump Operator, Munic. Water Dept., 200 W. Palm, Compton, Calif. (July '54) *MD*

McMahon, Thomas J.; *see* Behr-Manning Corp.

Miller, Myron D., Exec. Secy., Refrigeration Industry Safety Advisory Committee, 155 E. 44th St., New York 17, N.Y. (July '54) *MRD*

Morgan, Charles P., & Assoc., John M. Toups, Civ. Engr., 608 F. & M. Bldg., 320 Pine Ave., Long Beach 12, Calif. (Corp. M. July '54) *MRD*

Munster, Town of, Harry T. Helton, Town Trustee, 805 Ridge Rd., Munster, Ind. (Corp. M. July '54) *MD*

New Miami Board of Public Affairs, Carl W. Winter, Supt., Water Works, New Miami, Ohio (Munic. Sv. Sub. July '54) *M*

Paul, George E., Asst. Chief Constr. Engr., American Water Works Service Co., Inc., 121 S. Broad St., Philadelphia 7, Pa. (July '54) *M*

Petersen, Henry T., Salesman, Collar Co., 2818 Tauroome Ave., Kansas City, Kan. (July '54) *PD*

Pogue, Kenneth F., Salesman, R. D. Wood Co., 6617 Snider Plaza, Dallas, Tex. (July '54)

Pollard, Clarence U., Foreman, Squaw Peak Filter Plant, Div. of Water & Sewers, 827 E. Jefferson, Phoenix, Ariz. (July '54)

Prather, B. Vall, Chemist, Mid Continent Petroleum Corp., 1222 S. Darlington, Tulsa, Okla. (July '54) *P*

Randall, Joseph L., Civ. Eng. Assoc., Dept. of Water & Power, Box 3669 Terminal Annex, Los Angeles 54, Calif. (July '54)

Rosson, Sam L., Gen. Mgr. & Vice-Pres., Ector Water Co., 417 Midland Tower, Midland, Tex. (July '54) *D*

San Luis Obispo Water Dept., E. Price Thompson, Supt., 990 Palm St., San Luis Obispo, Calif. (Munic. Sv. Sub. July '54) *MRPD*

Schmidt, Robert W., Prin. Filtration Chemist, South Dist. Filtration Plant, 3300 E. Cheltenham Pl., Chicago 49, Ill. (July '54) *MP*

Schmidt, Victor R., Jr., Distr. Engr., Water Dept., Box 1160, Austin, Tex. (July '54) *D*

Schroeder, Donald G., Foreman, Service Dept., Water Dept., Tomah, Wis. (July '54)

Schultz, Samuel C., Foreman, Water Dept., 990 Palm St., San Luis Obispo, Calif. (July '54)

Selbert, Russell, Chairman, Board of Public Affairs, Box 332, Pataskala, Ohio (July '54) *MD*

Simon, R. E., Supt., Sewage Treatment Plant, Orlando, Fla. (July '54) *P*

South, Laurence, Dist. Engr., San. Eng. Div., Ontario Dept. of Health, 254 Springdale Blvd., Toronto, Ont. (July '54)

Stone, W. J., Indus. Chem. Sales, B. Preiser Co., Inc., 416 W. Washington St., Charleston, W.Va. (July '54)

Sylvester, William L., Sr. Civ. Engr. & Director of Public Relations, Dept. of Public Works, Municipal Bldg., New York 7, N.Y. (July '54) *MP*

Thompson, E. Price; *see* San Luis Obispo (Calif.) Water Dept.

Toups, John M.; *see* Morgan, Charles P., & Assoc.

Wolr, C. Victor F., Chief, Eng. & Architectural Div., Eng. & Water Resources Branch, Dept. of Northern Affairs & National Resources, Norlite Bldg., 150 Wellington St., Ottawa 4, Ont. (July '54) *PD*

Wesley, Carl, Jr., San. Engr., San. Eng. Branch, Eng. Research & Development, Army CE, Fort Belvoir, Va. (July '54) *RP*



If you have a water problem of any size or type—write us. With over 50 years of experience—conditioning water—We Can Help You

A New Bulletin of Bulletins . . . FREE on Request



HUNGERFORD & TERRY, INC.

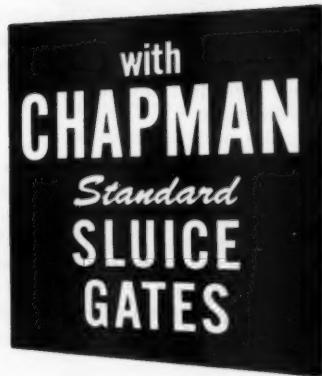
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WATER PROBLEM?

Photo on left shows a typical H & T fully automatic, municipal, zeolite water softening plant producing clear, iron free, soft water.

Operation of this automatic water treatment plant is by our electrically operated *poppet* type multiport valves—the valves which provide unequalled performance.

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Mean Fast Installation,
Low-Cost Maintenance



Fast installation, dependable trouble-free operation and low maintenance costs explain why Chapman Standard Sluice Gates are specified everywhere.

Interchangeable components make matchmarking or field alteration unnecessary, so installation is always quick and simple.

Uniform construction, from designs that have been developed in over seventy-five years' experience, means parts fit accurately and operate smoothly under the heaviest

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COMPOUND
C-I-60 CAST
IRON BOLTS**

Carson glands and bolts made of corrosion-resistant C-I-60 cast iron—last as long as cast iron pipe. Glands accommodate variations in pipe dimensions, insure uniform compression of rubber gasket.

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**Service
Lines**

Why reinforced concrete pipe was installed in a number of localities is discussed in a series of folders being distributed by Price Bros. Co., 1932 E. Monument Ave., Dayton 1, Ohio.

Liquid chemical feeding in small amounts by the use of a compact, inexpensive unit called the Feedrator is described in catalog sheet 70-50 of Fischer & Porter Co., 149 Jacksonville Rd., Hatboro, Pa. Some recommended applications are for feeding of hypochlorites; algicides; and slime, rust, and scale preventives.

Dall flow tube engineering information is provided by a 16-page technical bulletin, No. 115-L3, prepared by Builders-Providence, Inc., 345 Harris Ave., Providence, R.I. A British development, the instrument is said to produce less permanent head loss than any other velocity-increasing differential producer for measuring flow.

Catalog sheet 70-20 of the Fischer & Porter Co., 160 Jacksonville Rd., Hatboro, Pa., describes the automatic proportioning unit that may be used with the F&P chlorinator.

"Concrete in Water Works," a handsomely printed, 16-page booklet distributed by the Portland Cement Assn., 33 W. Grand Ave., Chicago 10, Ill., contains photographs of dams, intakes, pipelines, basins, tanks, buildings, and other facilities for the collection, treatment, and distribution of water. A flow diagram on the last page summarizes the water works applications for concrete.

(Continued on page 98 P&R)

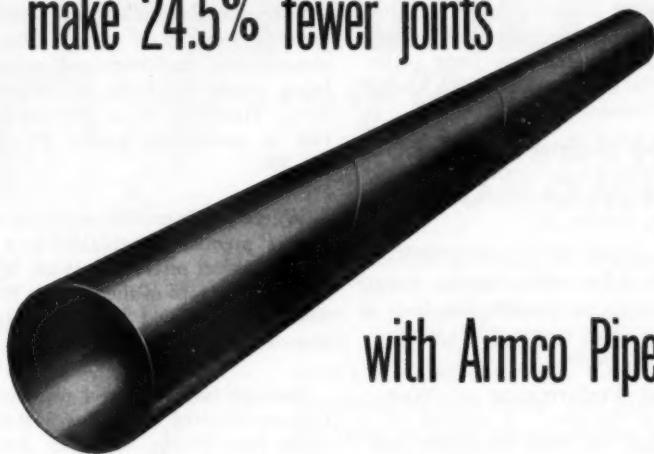
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make 24.5% fewer joints



with Armco Pipe

If you are using regular 40-foot pipe lengths, 132 joints will be required each mile. But by changing to 50-foot lengths of Armco Welded Steel Pipe, you need only 106 joints for the same distance. Thus, you can eliminate 26 joints—or almost one out of every five.

Besides cutting installation costs, the longer lengths of Armco Pipe also simplify hauling and handling.

With Armco Pipe it is easy to meet strength and capacity needs for your supply line, force main or water works piping. Diameters range from 6 to 36 inches; wall thicknesses are from 9/64- to 1/2-inch.

Outside coatings are supplied to A.W.W.A. specifications, and a spun enamel lining will prevent tuberculation. Write us for more data. Armco Drainage & Metal Products, Inc., Welded Pipe Sales Div., 2364 Curtis St., Middletown, Ohio. Subsidiary of Armco Steel Corporation. In Canada: write Guelph, Ontario.

ARMCO WELDED STEEL PIPE



Meets A. W. W. A. Steel Water Pipe Specifications

Service Lines

(Continued from page 96 P&R)

A waterstop intended to be installed after concrete has been placed is the subject of a folder on the Igas Joint Sealer. Copies may be obtained from Sika Chemical Corp., Passaic, N. J.

Cat Diesel Engines with hydraulic torque converters are described in a booklet, No. D457, available from Caterpillar Tractor Co., Peoria, Ill.

A Comminutor Engineering Manual has been issued to Worthington Corp., Harrison, N.J., to describe its line of equipment to shred coarse solids for sewage treatment plants.

"Practical Performance of Water-Conditioning Gadgets," a reprint of a technical paper on water treatment cure-alls, is being distributed by Hall Labs., Inc., Hagan Bldg., Pittsburgh 30, Pa.

"Trouble Savers"—preventive maintenance circulars on various types of air compressors, turbines, and pumps, are being made available by Worthington Corp., Harrison, N.J. The complete series is known as mailer PC-305 and PC-306.

Water hammer elimination on the customers' premises is promised by a booklet on the subject offered by Wade Mfg. Co., Elgin, Ill. Hero of the work is the Wade Shokstop, a sealed bellows designed to absorb the water shock waves.

Storage tanks of steel plate construction are featured in Catalog 54B of Hammond Iron Works, 630—5th Ave., New York 20, N.Y. The booklet contains 24 pages of design data and photographs.

BELCO

An organization of engineers engaged in the design, development and fabrication of equipment for "Removal of Water Impurities". Belco technicians, chemists and electronic control specialists have designed and furnished water treating installations ranking from the smallest to the largest in the world. For a discussion or analysis of your problems call a Belco man.

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RESETTERS

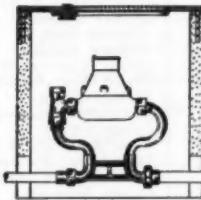
Until the Ford Resetter was developed the only way to raise a too-low meter was to dig up and remake the setting. The modern way to do the job is to remove the meter from between the old couplings, insert the Resetter and connect the meter between the flanged copper tubes.



RINGSTYLE COUPLINGS

The Ringstyle idea of putting the meter nut on the coupling body from the flange end permits designing meter couplings for attaching direct to iron pipe or copper tubing. There are savings in fittings, joints, labor and space.

When a meter-servicing chore seems to require more time and bother than it is worth, Ford engineers usually come up with a new idea to save time and cut costs. Each of the products in this space was pioneered by Ford to solve an expensive service problem. It pays to refer your problems to Ford FIRST.



COPPERSETTERS

The Coppersetter is a complete meter mounting and has been widely adopted for outside meter settings in shallow and medium depth service lines. The word is copyrighted; there is no Coppersetter except that made by Ford.

TESTERATE INDICATOR

It is important to know the rate of flow at which a meter is tested. The Testerate Indicator shows the rate instantly, clearly and accurately. Introduced in 1938, there are almost two thousand in service.



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Diaphragms, Pump:

Dorr Co.

Morse Bros. Mchly. Co.

Southern Pipe & Casing Co.

Engines, Hydraulic:

Ross Valve Mfg. Co.

Engineers and Chemists:

(See Prof. Services, pp. 25-29)

Feedwater Treatment:

Allis-Chalmers Mfg. Co.

Belco Industrial Equipment Div.

Calgon, Inc.

Cochrane Corp.

Graver Water Conditioning Co.

Hungerford & Terry, Inc.

Infilco Inc.

Permutit Co.

Ferric Sulfate:

Tennessee Corp.

Filter Materials:

Anthracite Equipment Corp.

General Filter Co.

Johns-Manville Corp.

Infilco Inc.

Northern Gravel Co.

Permutit Co.

Trinity Valley Iron & Steel Co.

Filters, incl. Feedwater:

Cochrane Corp.

Dorr Co.

Infilco Inc.

Morse Bros. Mchly. Co.

Permutit Co.

Roberts Filter Mfg. Co.

Ross Valve Mfg. Co.

Filtration Plant Equipment:

Chain Belt Co.

Cochrane Corp.

Filtration Equipment Corp.

General Filter Co.

Graver Water Conditioning Co.

Hungerford & Terry, Inc.

Infilco Inc.

F. B. Leopold Co.

Omega Machine Co. (Div., B-I-F
Industries)

Permutit Co.

Roberts Filter Mfg. Co.

Stuart Corp.

Welsbach Corp., Ozone Processes
Div.

Fittings, Copper Pipe:

Dresser Mfg. Div.

M. Greenberg's Sons

Hays Mfg. Co.

James Jones Co.

Mueller Co.

Fittings, Tees, Eills, etc.:

American Cast Iron Pipe Co.

American Locomotive Co.

Carlton Products Corp.

Cast Iron Pipe Research Assn.

James B. Clow & Sons

Crane Co.

Dresser Mfg. Div.

James Jones Co.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

McWane Cast Iron Pipe Co.

Pacific States Cast Iron Pipe Co.

Trinity Valley Iron & Steel Co.

United States Pipe & Foundry Co.

R. D. Wood Co.

Flocculating Equipment:

Chain Belt Co.

Cochrane Corp.

Dorr Co.

General Filter Co.

Infilco Inc.

Permutit Co.

Stuart Corp.

Fluoride Chemicals:

American Agricultural Chemical Co.

Blockson Chemical Co.

Henry Sundheimer Co.

Fluoride Feeders:

Builders-Providence, Inc.

Omega Machine Co. (Div., B-I-F
Industries)

Wallace & Tiernan Co., Inc.

Furnaces:

Jos. G. Pollard Co., Inc.

Gages, Liquid Level:

Builders-Providence, Inc.

Infilco Inc.

Simplex Valve & Meter Co.

**Gages, Loss of Head, Rate of
Flow, Sand Expansion:**

Builders-Providence, Inc.

Infilco Inc.

Northrop & Co., Inc.

Simplex Valve & Meter Co.

Gasholders:

Chicago Bridge & Iron Co.

Pittsburgh-Des Moines Steel Co.

**U. S. BUREAU
OF RECLAMATION
SPECIFIES**

**Concrete
Pressure Pipe**



When the U.S. Bureau of Reclamation builds a pipeline, it must last a long, long time.

This is why the Bureau has specified concrete pressure pipe in many projects under its jurisdiction throughout the Western States. In the State of California alone, approximately 3,000,000 feet of concrete pressure pipe have been used in diameters ranging from 12" through



84", and for heads up to 650 feet. These jobs include the Coachella Valley Project, the Cachuma Project near Santa Barbara, both barrels of the San Diego Aqueduct, and the Central Valley Project.

Large pipe distribution systems, often calling for heads of 200 feet and over, are jobs for concrete pressure pipe. So, when your city is planning a water transmission system with either low or high heads be sure to get the facts on concrete pressure pipe.

Member companies
manufacture
concrete pressure pipe
in accordance with
nationally recognized
specifications

**Concrete
PRESSURE
PIPE**

**AMERICAN CONCRETE
PRESSURE PIPE
ASSOCIATION**
228 North LaSalle Street
Chicago 1, Illinois

WATER FOR GENERATIONS TO COME

Gaskets, Rubber Packing:James B. Clow & Sons
Johns-Manville Corp.**Gates, Shear and Sluice:**
Armclo Drainage & Metal Products, Inc.Chapman Valve Mfg. Co.
James B. Clow & Sons
Morse Bros. Mchly. Co.
Mueller Co.
R. D. Wood Co.**Gears, Speed Reducing:**
DeLaval Steam Turbine Co.
Philadelphia Gear Works, Inc.**Glass Standards—Colorimetric Analysis Equipment:**Klett Mfg. Co.
Wallace & Tiernan Inc.**Goosenecks (with or without Corporation Stops):**James B. Clow & Sons
Hays Mfg. Co.
James Jones Co.
Mueller Co.**Hydrants:**James B. Clow & Sons
Darling Valve & Mfg. Co.
M. Greenberg's Sons
James Jones Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fitting Co.
Mueller Co.Pacific States Cast Iron Pipe Co.
A. P. Smith Mfg. Co.
Rensselaer Valve Co.
R. D. Wood Co.**Hydrogen Ion Equipment:**
Wallace & Tiernan Inc.**Ion Exchange Materials:**Cochrane Corp.
General Filter Co.
Hungerford & Terry, Inc.
Infico Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Rohm & Haas Co.**Iron Removal Plants:**American Well Works
Belco Industrial Equipment Div.
Chain Belt Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infico Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Welsbach Corp., Ozone Processes Div.**Jointing Materials:**Atlas Mineral Products Co.
Hydraulic Development Corp.
Johns-Manville Corp.
Leadite Co., Inc.**Joints, Mechanical, Pipe:**American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
McWane Cast Iron Pipe Co.
Pacific States Cast Iron Pipe Co.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.**Leak Detectors:**

Jos. G. Pollard Co., Inc.

Lime Sickers and Feeders:Dorr Co.
General Filter Co.
Infico Inc.
Omega Machine Co. (Div., B-I-F Industries)
Permutit Co.**Magnetic Dipping Needles:**

W. S. Darley & Co.

Meter Boxes:Ford Meter Box Co.
Pittsburgh Equitable Meter Div.

Universal Concrete Pipe Co.

Meter Couplings and Yokes:

Badger Meter Mfg. Co.

Dresser Mfg. Div.

Ford Meter Box Co.

Hays Mfg. Co.

Hersey Mfg. Co.

James Jones Co.

Mueller Co.

Neptune Meter Co.

Pittsburgh Equitable Meter Div.

Welsbach Corp., Kitson Valve Div.

Worthington-Gamon Meter Co.

Meter Reading and Record Books:

Badger Meter Mfg. Co.

Meter Testers:

Badger Meter Mfg. Co.

Ford Meter Box Co.

Hersey Mfg. Co.

Neptune Meter Co.

Pittsburgh Equitable Meter Div.

Meters, Domestic:

Badger Meter Mfg. Co.

Buffalo Meter Co.

Hersey Mfg. Co.

Neptune Meter Co.

Pittsburgh Equitable Meter Div.

Well Machinery & Supply Co.

Worthington-Gamon Meter Co.

Meters, Filtration Plant, Pumping Station:

Builders-Providence, Inc.

Foster Eng. Co.

Infico Inc.

Simplex Valve & Meter Co.

Meters, Industrial, Commercial:

Badger Meter Mfg. Co.

Buffalo Meter Co.

Builders-Providence, Inc.

Hersey Mfg. Co.

Neptune Meter Co.

Pittsburgh Equitable Meter Div.

Simplex Valve & Meter Co.

Well Machinery & Supply Co.

Worthington-Gamon Meter Co.

Mixing Equipment:

Chain Belt Co.

General Filter Co.

Infico Inc.

Ozonation Equipment:

Welsbach Corp., Ozone Processes Div.

Pipe, Asbestos-Cement:

Johns-Manville Corp.

Keasbey & Mattison Co.

Pipe, Brass:

American Brass Co.

Pipe, Cast Iron (and Fittings):

American Cast Iron Pipe Co.

Cast Iron Pipe Research Assn.

James B. Clow & Sons

Crane Co.

McWane Cast Iron Pipe Co.

Pacific States Cast Iron Pipe Co.

Trinity Valley Iron & Steel Co.

United States Pipe & Foundry Co.

R. D. Wood Co.

Pipe, Cement Lined:

Cast Iron Pipe Research Assn.

James B. Clow & Sons

McWane Cast Iron Pipe Co.

Pacific States Cast Iron Pipe Co.

United States Pipe & Foundry Co.

R. D. Wood Co.

Pipe Coatings and Linings:

The Barrett Div.

Cast Iron Pipe Research Assn.

Centriline Corp.

Koppers Co., Inc.

Reilly Tar & Chemical Corp.

Pipe, Concrete:

American Concrete Pressure Pipe Assn.

American Pipe & Construction Co.

Lock Joint Pipe Co.

Universal Concrete Pipe Co.

Pipe, Copper:

American Brass Co.

Pipe Cutters:

James B. Clow & Sons

Ellis & Ford Mfg. Co.

Jos. G. Pollard Co., Inc.

Reed Mfg. Co.

A. P. Smith Mfg. Co.

Pipe Jointing Materials; see Jointing Materials**Pipe Locators:**

W. S. Darley & Co.

Jos. G. Pollard Co., Inc.

Pipe, Steel:

American Locomotive Co.

Armclo Drainage & Metal Products, Inc.

Bethlehem Steel Co.

Plugs, Removable:

James B. Clow & Sons

Jos. G. Pollard Co., Inc.

A. P. Smith Mfg. Co.

Pressure Regulators:

Allis-Chalmers Mfg. Co.

Foster Eng. Co.

Mueller Co.

Ross Valve Mfg. Co.

Pumps, Boiler Feed:

DeLaval Steam Turbine Co.

Pumps, Centrifugal:

Allis-Chalmers Mfg. Co.

American Well Works

DeLaval Steam Turbine Co.

Morse Bros. Mchly. Co.

C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:

Infico Inc.

Proportioners, Inc.

Wallace & Tiernan Inc.

Pumps, Deep Well:

American Well Works

Layne & Bowler, Inc.

Pumps, Diaphragm:

Dorr Co.

Morse Bros. Mchly. Co.

Pumps, Hydrant:

W. S. Darley & Co.

Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:

Ross Valve Mfg. Co.

Pumps, Sewage:

Allis-Chalmers Mfg. Co.

DeLaval Steam Turbine Co.

C. H. Wheeler Mfg. Co.

Pumps, Sump:

DeLaval Steam Turbine Co.

C. H. Wheeler Mfg. Co.

Pumps, Turbine:

DeLaval Steam Turbine Co.

Layne & Bowler, Inc.

Recorders, Gas Density, CO₂, NH₃, SO₂, etc.:

Permutit Co.

Wallace & Tiernan Inc.

Recording Instruments:

Infico Inc.

Wallace & Tiernan Inc.

Reservoirs, Steel:

Chicago Bridge & Iron Co.

Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves; see Clamps

NOW...

LOSS-OF-WEIGHT RECORDING

FOR SERIES A-635

W&T VOLUMETRIC FLUORIDATORS

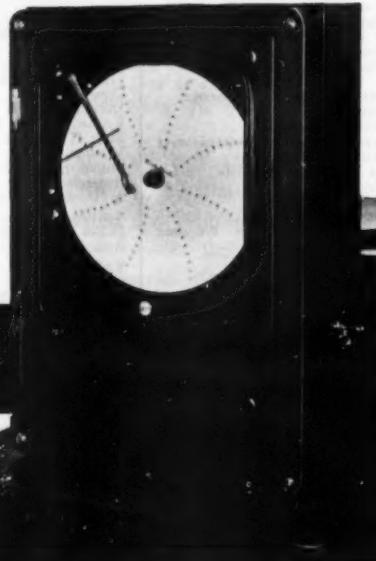
Volumetric feeding with its simplicity, dependability and economy can now be supplemented with the following benefits of loss-of-weight recording:

A PERMANENT RECORD OF:

- Chemical fed during any period
- Periods of feeder operation
- Time of hopper loading
- Quantity of chemical added at each loading

PLUS THE CONVENIENCE OF:

- Direct reading register that gives the hopper contents at a glance
- Visible and audible alarms that warn when the hopper contents are low
- A mechanical poise weight drive for rebalancing after loading



WALLACE & TIERNAN
COMPANY

25 MAIN STREET, BELLEVILLE 9, N.J.

TP-75-C-2 gives further information on the W&T Series A-635 Volumetric Fluoridator

Sleeves and Valves, Tapping:

James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.

Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:

General Filter Co.
Permutit Co.

Sodium Hexametaphosphate:

Blockson Chemical Co.
Calgon, Inc.

Sodium Silicate:

Philadelphia Quartz Co.

Softeners:

Belco Industrial Equipment Div.
Cochrane Corp.

Dorr Co.

General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.

Infico Inc.

Permutit Co.

Roberts Filter Mfg. Co.

Walker Process Equipment, Inc.
Softening Chemicals and Com-

pounds:

Calgon, Inc.

Cochrane Corp.

General Filter Co.

Infico Inc.

Permutit Co.

Tennessee Corp.

Standpipes, Steel:

Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Steel Plate Construction:

American Locomotive Co.

Bethlehem Steel Co.

Chicago Bridge & Iron Co.
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:

Hays Mfg. Co.

James Jones Co.

Mueller Co.

Welsbach Corp., Kitson Valve Div.

Storage Tanks; see Tanks**Strainers, Suction:**

James B. Clow & Sons

M. Greenberg's Sons

Johnson, Edward E., Inc.

R. D. Wood Co.

Surface Wash Equipment:

Cochrane Corp.

Permutit Co.

Swimming Pool Sterilization:

Everson Mfg. Corp.

Omega Machine Co. (Div., B-I-F Industries)

Proportioners, Inc.

Wallace & Tiernan Inc.

Welsbach Corp., Ozone Processes Div.

Tanks, Steel:

American Locomotive Co.

Bethlehem Steel Co.

Chicago Bridge & Iron Co.

Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:

Hays Mfg. Co.

Mueller Co.

A. P. Smith Mfg. Co.

Tapping Machines, Corp.:

Hays Mfg. Co.

Mueller Co.

Welsbach Corp., Kitson Valve Div.

Taste and Odor Removal:

Cochrane Corp.

General Filter Co.
Industrial Chemical Sales Div.
Infico Inc.
Permutit Co.
Proportioners, Inc.
Wallace & Tiernan Inc.
Welsbach Corp., Ozone Processes Div.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):

Wallace & Tiernan Inc.

Turbines, Steam:

DeLaval Steam Turbine Co.

Turbines, Water:

DeLaval Steam Turbine Co.

Valve Boxes:

James B. Clow & Sons

Ford Meter Box Co.

M & H Valve & Fittings Co.

Mueller Co.

Pacific States Cast Iron Pipe Co.

Rensselaer Valve Co.

A. P. Smith Mfg. Co.

Trinity Valley Iron & Steel Co.

R. D. Wood Co.

Valve-Inserting Machines:

Mueller Co.

A. P. Smith Mfg. Co.

Valves, Altitude:

Ross Valve Mfg. Co., Inc.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:

Backflow Engineering & Equipment Co.

Chapman Valve Mfg. Co.

James B. Clow & Sons

Crane Co.

DeZurik Shower Co.

M. Greenberg's Sons

M & H Valve & Fittings Co.

Mueller Co.

Rensselaer Valve Co.

R. D. Wood Co.

Valves, Detector Check:

Hersey Mfg. Co.

Valves, Electrically Operated:

Belco Industrial Equipment Div.

Chapman Valve Mfg. Co.

James B. Clow & Sons

Crane Co.

Darling Valve & Mfg. Co.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

Philadelphia Gear Works, Inc.

Rensselaer Valve Co.

A. P. Smith Mfg. Co.

Valves, Float:

James B. Clow & Sons

Ross Valve Mfg. Co., Inc.

Valves, Gate:

Chapman Valve Mfg. Co.

James B. Clow & Sons

Crane Co.

Darling Valve & Mfg. Co.

Dresser Mfg. Co.

James Jones Co.

Kennedy Valve Mfg. Co.

Ludlow Valve Mfg. Co., Inc.

M & H Valve & Fittings Co.

Mueller Co.

Pacific States Cast Iron Pipe Co.

Rensselaer Valve Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

Valves, Hydraulically Operated:

Chapman Valve Mfg. Co.

James B. Clow & Sons

Crane Co.

Darling Valve & Mfg. Co.

DeZurik Shower Co.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

Philadelphia Gear Works, Inc.

Rensselaer Valve Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

Valves, Large Diameter:

Chapman Valve Mfg. Co.

James B. Clow & Sons

Crane Co.

Darling Valve & Mfg. Co.

Kennedy Valve Mfg. Co.

Ludlow Valve Mfg. Co., Inc.

M & H Valve & Fittings Co.

Mueller Co.

Rensselaer Valve Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

Valves, Regulating:

Crane Co.

DeZurik Shower Co.

Foster Eng. Co.

Mueller Co.

Ross Valve Mfg. Co.

Valves, Swing Check:

Chapman Valve Mfg. Co.

James B. Clow & Sons

Crane Co.

Darling Valve & Mfg. Co.

M. Greenberg's Sons

M & H Valve & Fittings Co.

Mueller Co.

Rensselaer Valve Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

Waterproofing:

Gulf States Asphalt Co.

Inertol Co., Inc.

Water Softening Plants; see Softeners**Water Supply Contractors:**

Layne & Bowler, Inc.

Water Testing Apparatus:

Wallace & Tiernan Inc.

Water Treatment Plants:

Allis-Chalmers Mfg. Co.

American Well Works

Belco Industrial Equipment Div.

Chain Belt Co.

Chicago Bridge & Iron Co.

Cochrane Corp.

Dorr Co.

General Filter Co.

Graver Water Conditioning Co.

Hungerford & Terry, Inc.

Infico Inc.

Permutit Co.

Pittsburgh-Des Moines Steel Co.

Roberts Filter Mfg. Co.

Walker Process Equipment, Inc.

Wallace & Tiernan Inc.

Welsbach Corp., Ozone Processes Div.

Well Drilling Contractors:

Layne & Bowler, Inc.

Well Screens:

Johnson, Edward E., Inc.

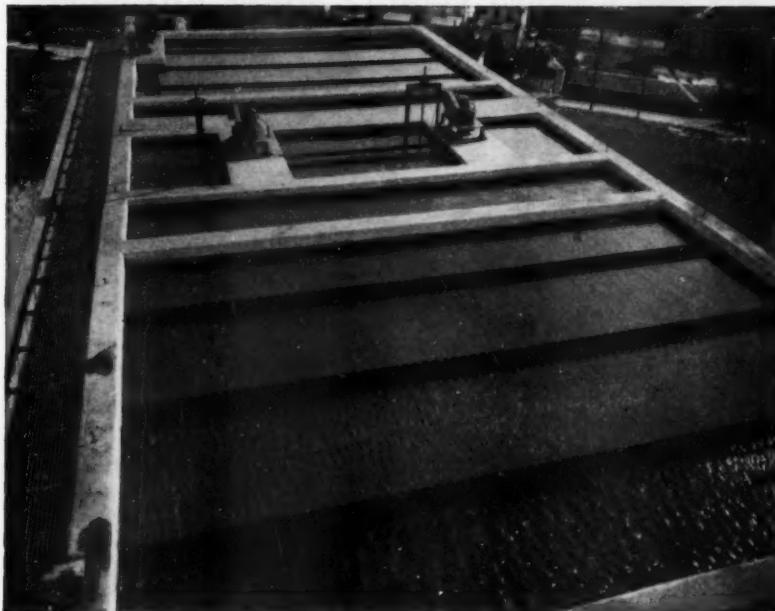
Wrenches, Ratchet:

Dresser Mfg. Div.

Zeolite; see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1953 AWWA Directory.

FOR WATER SOFTENING . . . TURBIDITY AND COLOR REMOVAL
INDUSTRIAL WASTE TREATMENT . . .



Walker Process CLARIFLOW installation for turbidity removal at Brackenridge, Pa. This unit handles 2000 gpm in tank 55'x24'x15' AWD. The Chester Engineers, Pittsburgh, Pa.—Consulting Engineers.

The Clariflow combines flocculation, good fluid mechanics and clarification in a relatively small tank. Mixing, flocculation, stilling and sedimentation are independently operated and controlled. The positive control of flocculation and clarification enables the operator to readily select the most economical method of operation when handling changeable water conditions.

Adaptable to circular, rectangular or square tanks the CLARIFLOW is a true vertical flow unit. Short circuiting tendencies are eliminated by means of exclusive multiple, tangential diffusers which simultaneously and equally distribute the flow. Balanced multiple surface weir troughs make efficient use of short detention periods and insure clarified overflows.

Write for Bulletin 6W46

WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.
Factory — Engineering Offices — Laboratories
Aurora, Illinois

Q-

What happens when a Rockwell-Empire Type 12 Meter FREEZES?

A-

All interior parts
SEPARATE to
prevent damage!



In this meter the internal castings are jointed and held together without the use of screws or bolts. Thus, when the meter freezes and the frost bottom breaks, all the parts separate and are free to move with the expanding ice. There is no strain or distortion such as can occur in meters either having parts bolted together or with assemblies that are directly attached to the meter case.

Ask your Rockwell representative to demonstrate this and the many other money-saving, revenue-building features in the Empire Type 12 design, or write for bulletin W-802.



THE EMPIRE TYPE 14

—for use in warm climates. An all-bronze meter having the superior performance of the piston type design and highly resistant to the effects of electrolytic action. Has fewer working parts than any other meter. Fully described in bulletin W-801.



SEE HOW IT WORKS



Jointed castings separate to relieve against distortion.

ROCKWELL MANUFACTURING COMPANY

PITTSBURGH 8, PA. Atlanta Boston Chicago Houston Los Angeles
N. Kansas City New York Philadelphia Pittsburgh San Francisco Seattle Tulsa

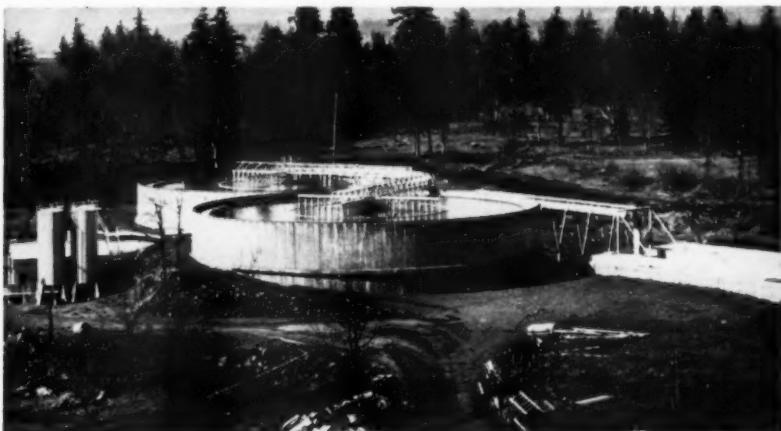
In Canada: Peacock Brothers Limited



in water treatment problems...

you won't find identical twins.

No two water treatment problems are exactly alike. The right solution to each can only be arrived at after a careful study of the local conditions. Variables such as raw water composition, rate of flow and results required automatically rule out the cure-all approach. The installation shown below is a good example of how equipment should be selected to fit the job . . . and not vice versa.



At St. Helens Pulp & Paper Company

**Fluctuating feed characteristics and changing process needs
require conventional treatment in combination units**

Clear, process water for production of bleach pulp has been a serious problem at the St. Helens Pulp & Paper Company mill at St. Helens, Oregon. Raw water characteristics fluctuate widely because of the tidal action of the Pacific, and the presence of some wastes in the Willamette and Columbia Rivers which join just below the plant. Feed volume fluctuates too — because of changing process needs.

In 1952, water analysis showed 14 to 68 ppm total hardness, 20 to 200 ppm turbidity and 20 to

50 ppm color. The two 120' dia. Dorco Clariflocculators shown above were specified to produce 20 MGD of finished water containing no more than 5 ppm color and 5 ppm hardness. Combination units, operating at conventional rates of flow, are ideally suited for the changing conditions at St. Helens.

For more information on the complete line of Dorr water treatment units, write for Bulletin No. 9141 to The Dorr Company, Stamford, Conn. in Canada, 26 St. Clair Avenue East, Toronto 5.

Every day, nearly 8 billion gallons of water are treated in Dorr equipment.



LEADITE

Trade Mark Registered U. S. Patent Office

Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains **MUST BE GOOD,—MUST BE DEPENDABLE,—** and that is just why so many Engineers, Water Works Men and Contractors aim to **PLAY ABSOLUTELY SAFE**, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

*The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%*

THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

